MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. CXXX.

EDITED BY

J. H. T. TUDSBERY, D.Sc., M. INST. C.E., SECRETARY.

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ADVERTISEMENT.

The Institution as a body is not responsible either for the statements made, or for the opinions expressed, in the following pages.

NOTICE.

To insure the punctual delivery of the Minutes of Proceedings, and of other communications from the Institution, it is essential that every change of address should be notified without delay to—

THE SECRETARY,
THE INSTITUTION OF CIVIL ENGINEERS,
Great George Street, Westminster, S.W.

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THE

INSTITUTION

OF

CIVIL ENGINEERS.

IX

SESSION 1896-97.—PART IV.

SECT. I.—MINUTES OF PROCEEDINGS.

SPECIAL GENERAL MEETING.

30 March, 1897.

JOHN WOLFE BARRY, C.B., F.R.S., President, in the Chair.

THE following Notice convening the Meeting was read:—

NOTICE IS HEREBY GIVEN that a Special General Meeting of The Institution of Civil Engineers will be held at the Institution, Great George Street, Westminster, on Tuesday, the 30th day of March, 1897, at 4.30 o'clock, for the purpose of considering, and, if approved, enacting, the alterations of the By-laws referred to in the note annexed.

J. H. T. TUDSBERY, *Secretary.*

Great George Street, Westminster,
22 March, 1897.

the note referred to therein being taken as read.

After explaining the objects sought by the Council in the introduction of the changes in the By-laws recommended and indicated in a draft copy of Sections II, III, IV and V, and Forms A and G in the Appendix, and the re-lettering of the remaining forms, the President moved, and Mr. Preece, Vice-President, seconded, the adoption of those portions of the alterations which applied to the conditions of election and admission into the Institution.

The resolution was, after discussion, put to the Meeting and carried unanimously.

The President then moved, Sir Douglas Fox, Vice-President, seconded, and it was, after discussion, Resolved unanimously—

"That those portions of the alterations recommended which apply to the procedure for expelling persons from the Institution be adopted."

The President moved, Mr. Mansergh, Vice-President, seconded, and it was, after discussion, Resolved unanimously—

"That such portions of the alterations as apply to Life Composition and Contribution to the Funds be adopted."

The President moved, Mr. Preece, Vice-President, seconded, and it was Resolved unanimously—

"That the portions of the alterations recommended which apply to the definition of the several classes composing the Institution and the use of the term 'Associate Members,' with the insertion of that term after the word 'Members' in the title of Section III, be adopted."

The Meeting then terminated.

(Signed) J. WOLFE BARRY,
Chairman of the Meeting.

ALTERATION OF BY-LAWS, 1897.

NOTE SHOWING THE GENERAL TENOUR AND OBJECTS OF THE PROPOSED ALTERATIONS INDICATED IN THE ACCOMPANYING COPY OF SECTIONS II., III., IV. AND V.

i.—After very careful deliberation, the Council consider that the time has arrived when, in the interests of the profession and of the public, more satisfactory assurance should be afforded of the education and training of Candidates for Associate Membership of the Institution.

The existing By-laws require the Council to consider these matters in connection with candidature; but it is thought that Candidates should afford more definite proof of their general and scientific knowledge than under the present system.

The majority of those elected give such proof, in respect of general education, by their degrees and diplomas, or by the fact of their previous admission as Students of the Institution; and it is deemed that, in the interests of the whole body, a definite standard of attainment, not only in general education but also in those branches of Physical Science which form the basis of Engineering (apart from any standard of practical Engineering knowledge) should now be laid down as a qualification for election to Associate Membership.

The Council are of opinion that the Institution should itself prescribe and hold the necessary examinations, whilst recognising equally those of other bodies which are of a proper standard. Further, that the Council should have power to substitute for examination a Paper or a Thesis, or to dispense with such proof entirely in special cases. Finally, that election or transfer to full membership should continue to rest upon evidence of skill and experience in practical work without examination being required, the limit of age for this class being raised from twenty-five to thirty years.

The Council therefore propose that Sections II. III. and IV. of the By-laws be modified in these respects, and by the omission of some superfluous words, according to the draft herewith.

ii.—A second question to which the attention of the Council has been directed is the complex process for the removal of any member guilty of grave pro-

fessional misconduct. A strong feeling is believed to exist that the Council should have the power to deal with such cases—as in other important societies, such as the Royal College of Surgeons, the Royal Institute of British Architects, the Institute of Chartered Accountants, and others. The members are therefore asked to approve the alteration of Art. 11 of Section III., according to the accompanying draft. It is thought that a majority of eleven-twelfths of the Council, as now proposed, will afford a sufficient guarantee of individual rights.

iii.—An important matter affecting the financial position of the Institution is the amount payable as life-composition in lieu of annual subscription. The Council have been advised that the actuarial values of the life-compositions are, having regard to the present value of money, too low—to the manifest disadvantage of annual subscribers. Again, a compounder residing abroad has an anomalous advantage over his fellow in the United Kingdom, which, as an annual subscriber, he does not possess. The Council propose that Sect. V. of the By-laws should be modified according to the draft—placing the matter of life-composition upon a more equitable basis, and rectifying the rules so as to state the existing practice in some respects more precisely.

iv.—A verbal alteration is proposed, whereby the class of Associate Members may be defined and referred to in the By-laws in accordance with the definition given in the Report of the Council for the Session 1878–1879.

Draft of Proposed Alterations of the By-Laws and Regulations. Sects. II., III., IV., and V.

NOTE.—The italicised portions indicate the new words proposed, the remainder follows the original text, words to be omitted being ruled through.

Section II.

Constitution.

1. The Institution of Civil Engineers shall consist of Members, *of Associate Members*, of ~~such~~ Associates ~~as are hereinafter declared to be~~ entitled to the privileges of Corporate Membership, and of Honorary Members. All such Members, *Associate Members*, Associates, and Honorary Members may hereafter be referred to as Corporate Members. The Institution may also have attached to it Associates who are not entitled to the privileges of Corporate Membership, and Students.

2. Members shall comprise every person, ~~other than an Associate or an Honorary Member~~, who on the 2nd of December, 1878, was on the Register as a Member: and every person thereafter elected or transferred into the class of Members. Every Candidate for election or transfer into the class of Members shall be more than *thirty* ~~twenty-five~~ years of age, and *shall* come within one of the following conditions:—

He shall have been regularly educated as a Civil Engineer ~~according to the usual routine of pupilage, and~~ *shall* have had subsequent employment for at least five years and shall be actually engaged at the time of his application for election, in responsible situations as Resident Engineer, or otherwise, in some of the branches defined by the Charter as constituting the profession of a Civil Engineer; or

He shall have practised on his own account in the profession of a Civil

Engineer for at least five years, and shall have acquired a considerable degree of eminence in the same.

3. *ASSOCIATE MEMBERS shall comprise every person who, being a Civil Engineer by profession, was on the register as an Associate on the 2nd December*, 1878, *and every person thereafter elected into the class of Associate Members.* ~~ASSOCIATES shall be divided into those who are and those who are not entitled to the privileges of Corporate Membership.~~

Every candidate for election into the class of Associate Members shall be more than twenty-five years of age, (*a*) *He* shall have been regularly educated as a Civil Engineer, *shall have passed such examination or examinations as are appointed or are recognized by the Council*, and shall be actually engaged at the time of his application for election, in the design or in the construction of such works as are comprised within the profession of a Civil Engineer as defined by the Charter; or,

(*b*), He shall satisfy the Council that he has had a sufficient training, ~~and~~ that he has been engaged for at least five years and that he is actually engaged at the time of his application for election, in the design or in the construction of such works as are comprised within the profession of a Civil Engineer as defined by the Charter, *and shall furnish a satisfactory Thesis or Paper on a professional subject; or*,

(*c*), *He shall, whilst complying with either of the foregoing conditions as to training and occupation as set forth in the paragraphs (a and b), afford satisfactory proof to the Council of his fitness for election without either examination or the submission of a Thesis or Paper.*

4. ASSOCIATES ENTITLED TO THE PRIVILEGES OF CORPORATE MEMBERSHIP shall comprise every person who, *not being a Civil Engineer by profession*, was on the Register as an Associate on the 2nd of December, 1878, ~~and every person thereafter elected into the class of Associates entitled to the privileges of Corporate Membership.~~

5. ~~Candidates for election into the class of~~ ASSOCIATES NOT ENTITLED TO THE PRIVILEGES OF CORPORATE MEMBERSHIP shall be persons ~~of more than twenty-five years of age,~~ who are not Civil Engineers by profession, but whose pursuits constitute branches of Engineering, or who by their connection with Science or the Arts, or otherwise, are qualified to concur with Civil Engineers in the advancement of professional knowledge.

6. HONORARY MEMBERS shall be either distinguished individuals, who from their position are enabled to render assistance in the prosecution of public works, or persons eminent for science and experience in pursuits connected with the profession of a Civil Engineer, but who are not engaged in the practice of that profession in the United Kingdom or its dependencies.

~~All persons who at the date of the passing of these By-laws are on the Register as Honorary Members shall continue to be such.~~

7. STUDENTS shall be persons not under eighteen years of age, who are, or have been, pupils of Corporate Members of the Institution, *who have complied with the regulations of Sect. IV. of these By-laws*, and who have the object or intention of becoming engaged in the design or in the construction of such works as are comprised within the profession of a Civil Engineer as defined by the Charter; and such persons may continue Students until they attain the age of twenty-six years, but not longer.

8. The Officers of the Institution shall be a President, four Vice-Presidents, and other Members of Council to be elected or nominated under the By-laws.

who shall constitute the Council to direct and manage the concerns of the Institution; also two Auditors of Accounts, a Treasurer, and two Secretaries. Such Officers shall be elected or appointed annually in manner hereinafter directed.

9. Any Member, *Associate Member*, ~~Associate being a Corporate Member,~~ Associate, Honorary Member, or Student, having occasion to designate himself as belonging to the Institution, shall state the class to which he belongs, according to the following abbreviated forms, *viz.*, M. Inst. C.E., Assoc. M. Inst. C.E., Assoc. Inst. C.E., Hon. M. Inst. C.E., Stud. Inst. C.E.: ~~it being understood that those Associates on the Register on the 2nd of December, 1878, who are Civil Engineers by profession, and those Associates thereafter elected to the privileges of Corporate Membership, shall alone be entitled to use the abbreviated form Assoc. M. Inst. C.E.~~

SECTION III.

ELECTION, TRANSFER AND EXPULSION OF MEMBERS, *ASSOCIATE MEMBERS*, ASSOCIATES AND HONORARY MEMBERS.

1. Any person desirous of being elected a Member, *Associate Member*, Associate, or Honorary Member, must be proposed and recommended according to the Form A in the Appendix, in which the name, usual residence, and qualifications of the candidate shall be distinctly specified. ~~This form~~ *The proposal* must be signed by at least six Corporate Members certifying a personal knowledge of the candidate, and a full conviction of his qualifications, *and the candidate must sign the undertaking appended to the Form.*

2. The proposal so made, being delivered to the Secretary, shall be submitted to the Council, who ~~on approving the qualifications, shall determine the class for which the candidate is to be presented for ballot,~~ *shall consider the qualifications specified, and shall in the case of persons required by these By-laws to have passed Examinations appointed or recognized by the Council, or to have furnished Theses or Papers, satisfy themselves that the candidate has passed the necessary examination or examinations, or has furnished the necessary Thesis or Paper. The Council shall determine the class for which the candidate is to be presented for Ballot, and shall specify the same on the proposal. The Chairman of the Meeting of Council which approves, or (after being satisfied as aforesaid) finally approves, the eligibility of a candidate, shall sign the proposal which shall then* ~~The Chairman of the Council shall sign the proposal, which shall~~ be read at the next Ordinary Meeting of the Institution, and be placed in some conspicuous situation until the candidate is balloted for, and six clear days shall elapse between the reading of the proposal and the Ballot.

The Council shall cause to be held examinations for persons desirous of being elected Associate Members, and shall frame Regulations for such examinations, defining the times at which they shall be held, the subjects which they shall comprise, and the fees to be paid or deposited by candidates in respect of such examinations; and they may from time to time add to or vary or rescind any of the aforesaid regulations as it may appear to them to be necessary.

The examinations shall be directed by the Council, who shall obtain such assistance as may be necessary from qualified persons to be appointed by them examiners in such subjects as the Council may from time to time determine. The remuneration of such examiners shall be fixed by the Council. The Council may in their

discretion permit persons who are not at the time candidates for election to present themselves for examination, and if they pass such examination the Council may exempt them (wholly or partially) from further examination if they subsequently apply for election. After each examination held under the direction of the Council a report of the names of those who have passed shall be presented by the examiners to the Council. The Council shall have power to recognize such University degrees and Collegiate or other certificates as after scrutiny they may deem to prove a sufficient standard of attainment in the subjects referred to; and may exempt such graduates or holders of such certificates from passing the aforesaid examinations appointed and directed by the Council.

3. Any person whose proposal has been passed by the Council shall be duly informed of it by a letter *from the Secretary*, ~~according to Form C, enclosing an engagement (Form D); and he shall not be put up for ballot until he shall have returned the engagement (Form D), with his signature appended.~~

4. Ballots shall take place at the first Ordinary Meeting of the Institution in the Month of December in each year, and at the first Meeting in each ensuing month during the Session, and at the last Meeting but one in the Session. Only Corporate Members have the right of voting.

5. Every candidate shall be declared to be elected unless there be at least one negative vote for every four affirmative votes.

6. In any election a second ballot shall be granted, at the same Meeting, if it be demanded immediately by any three persons present having a right to vote.

7. In case of the non-election of any person balloted for no notice shall be taken thereof on the minutes.

8. The proposal for transferring any person from the class of *Associate Members* ~~entitled to the privileges of Corporate Membership~~ to the class of Members shall be according to Form ~~B~~ *C* in the Appendix. This form being subscribed by at least ten Corporate Members, and delivered to the Secretary, shall be submitted to the Council, who, subject to the conditions hereinbefore set forth, may, if they think fit, make the proposed transfer.

9. Any person duly elected a Member, *Associate Member*, Associate, or Honorary Member, or transferred from one class to another, shall be informed thereof without delay, by a letter, according to the Form ~~E~~ *D*, enclosing a promise (Form *E* ~~F~~), which promise the person elected or transferred must sign and return to the Secretary, and he must pay the admission fee and annual subscription for the current year (or the increase thereof in case of transfer) within two months after the date of his election or transfer which otherwise shall become void; but the Council may in particular cases extend the time.

10. Every individual elected, and having signed the Form ~~F~~ *E* in the Appendix, and the Register of the Institution, and having likewise made the proper payments, shall receive the diploma of his election. At the first Ordinary Meeting at which he is present, he shall, after having fulfilled the foregoing requirements, be introduced according to the ensuing form: *viz.* the President or Chairman of the Meeting, addressing him by name, shall say, "As President "(or as Chairman of this Meeting) of THE INSTITUTION OF CIVIL ENGINEERS, "I introduce Mr. A. B. as a Member, *Associate Member*, Associate, or Honorary Member (as the case may be)."

11. The Council shall have the right, by a majority of two-thirds of those present at a meeting of the Council, to expel from the Institution any Member, *Associate Member* or Associate who may be convicted, by a competent tribunal, of felony, embezzlement, larceny, or misdemeanour, or other offence

which, in the opinion of the Council, renders him unfit to be a member; and in case the *Council shall be of opinion that the conduct of any Member, Associate Member or Associate should become the subject of enquiry with a view of ascertaining whether there are grounds for his expulsion, or in case twenty or more Corporate Members shall think fit to draw up and sign a proposal for the expulsion of a Member, Associate Member or Associate on any ground whatever, and shall deliver the same to the Secretary to be laid before the Council for consideration, the Council shall make such enquiry as they deem adequate; and if they do not find sufficient reason for expulsion no entry of the enquiry shall be made in the Minutes; but if the Council by a majority of at least eleven-twelfths of those present at a Meeting of the Council specially summoned for the purpose and at which at least twelve Members of Council are present, do find good reason for expulsion of the Member, Associate Member or Associate on the ground that he has been guilty of disgraceful conduct in any professional respect they shall cause such person's name to be erased from the Register and thus expel him from the Institution. The Secretary shall give him notice according to Form G in the Appendix, and the Council shall report such erasure at the next Annual General Meeting.* ~~expulsion of any Member or Associate shall be judged expedient on any ground whatever by twenty Corporate Members, and they think fit to draw up and sign a proposal requiring such expulsion, the same being delivered to the Secretary, shall be by him laid before the Council for consideration. If the Council, after due enquiry, do not find reason to concur in the proposal, no entry thereof shall be made in any minutes, nor shall any public discussion thereon be permitted; but if the Council do find good reason for the proposed expulsion, they shall direct the Secretary to address a letter, according to the Form G in the Appendix, to the person proposed to be expelled, advising him to withdraw from the Institution. If that advice be followed, no entry shall be made on the Minutes, nor any public discussion on the subject be permitted; but if that advice be not followed, nor a satisfactory explanation given, the Council shall call a Special General Meeting of Corporate Members for the purpose of deciding on the question of expulsion; and if a majority of the persons present at such Special General Meeting, provided the number so present be not less than fifty, vote that such individual be expelled, the Chairman of that Meeting shall declare the same accordingly, and the Secretary shall communicate the same to the individual according to the Form H in the Appendix.~~

Section IV.

Admission and Privileges of Students.

1. *Upon producing evidence of having passed such examination or examinations in the subjects of general education as may be appointed or recognized by the Council, persons, between the ages of* 18 *and* 25 *years, may be admitted as* Students ~~may be admitted~~ by the Council on the recommendation (according to Form ~~A 2~~ *B* in the Appendix) of the Corporate Members under whom they are, or have been, pupils; and they may remain Students of the Institution, at and during the pleasure of the Council, until they attain the age of twenty-six years, when they shall cease to be Students.

The Council may cause to be held examinations for persons desirous of being admitted Students, and may frame regulations for such examinations, defining the times at which they shall be held, the subjects which they shall comprise, and the

fees to be paid or deposited by candidates in respect of such examinations; and the Council may from time to time add to or vary or rescind such of the aforesaid regulations as may appear to them to be necessary, and shall have power to recognize in their discretion University degrees and Collegiate or other certificates in lieu of examinations appointed under the provisions of this Section.

2. Any person admitted as a Student shall be informed thereof by letter (according to the Form *F* ~~E 1~~ in the Appendix) stating that the first year's subscription must be paid within two months, otherwise the admission will be void. When the first subscription shall have been paid he shall be entitled to attend the Ordinary Meetings, but not to vote at such Meetings, and to have the use of the Library (subject to such regulations as the Council may from time to time prescribe), as well as to receive a copy of the Minutes of Proceedings relating to each session during which he shall continue to be a Student.

3. Students of the Institution are eligible to compete for the premiums or prizes arising out of the "Miller Fund," and any other funds devoted by the Institution, or by any person or persons, for premiums or prizes for Students.

4. The Council may accord to Students other privileges, but subject to such terms, regulations, and restrictions, as they shall from time to time prescribe.

5. No Student will be allowed to introduce a stranger into the rooms of the Institution.

Section V.

Contributions to the Funds.

1. Those Members, *Associate Members*, Associates, and Students, whose place of business or whose residence is within ten miles of the General Post-Office, shall be considered Residents, and those beyond such limits Non-Residents.

2. On change of place of business or of residence, so as to go beyond or come within those limits before each annual contribution becomes due, the amount thereof shall vary accordingly.

3. Each resident Member shall pay four guineas, and each non-resident Member three guineas, per annum.

4. Each resident *Associate Member and* Associate shall pay three guineas, and each non-resident *Associate Member and* Associate two guineas and a half, per annum. *The subscription for the current year paid by an Associate Member shall, on his transfer to Membership, be taken as in part payment of his subscription as a Member for that year.*

5. Each resident Student shall pay two guineas, and each non-resident Student one guinea and a half, per annum. *The subscription for the current year paid by a Student shall, on his election to Associate Membership, be taken as in part payment of his subscription as an Associate Member for that year.*

6. Every new Member, *Associate Member* and Associate shall on admission to the Institution pay a fee of ten guineas; but no payment, other than the increased annual subscription, shall be due from an Associate *Member* on his transfer to Membership.

7. Any Member, *Associate Member*, or Associate, whose subscription is not in arrears, may, ~~if resident in the United Kingdom,~~ compound for future annual subscriptions by the payment of *sixty guineas* ~~fifty guineas. Any Member, or Associate, residing abroad, may compound by the payment of twenty-five guineas; but should he come to reside in the United Kingdom, he shall pay the remainder of the composition, viz., twenty-five guineas, or the usual annual subscription during such residence.~~ All such compositions shall be invested,

and the interest alone shall be appropriated to the current expenditure of the Institution, except by special direction of the Council on the report and recommendation of the Finance Committee.

8. All annual subscriptions are due on the first of January in each year for the year then commencing, and must be paid before the first of April of that year; any Member, *Associate Member*, Associate, or Student, whose subscription is in arrear shall not be entitled to attend any Meeting, *or to receive the publications*. The subscription of any Member, *Associate Member*, or Associate, elected at the Ballot in December, shall become due on the first of January next ensuing: and the subscription of any Student admitted in the month of November or December shall become due on the first of January next ensuing.

9. Every individual elected a Member, *Associate Member* or Associate, and every Student, shall be liable for the payment of his annual subscription, until he has signified to the Secretary, in writing, his desire to resign, having previously paid all arrears, or until he has forfeited his right to remain in, or to be attached to, the Institution.

10. Any person whose subscription is two years in arrear, that is to say, whose arrears and current subscription shall not have been paid on or before the first of April, shall be reported to the Council, who shall direct application to be made to him according to Form *H* ~~I~~; and in the event of its continuing one month in arrear, after such application, the Council shall have the power, after suitable remonstrance, by letter, in the form so provided (Form *I* ~~K~~), of erasing the name of the defaulter from the Register or lists of the Institution.

11. In the case of any Corporate Member who has been long distinguished in his professional career, but who, from ill health, advanced age, or other sufficient cause, does not continue to carry on a lucrative practice, the Council, if they find good reason for the remission of the annual subscription, may so remit it. Also they may remit any arrears which are due from such an individual; or may accept a collection of books, or drawings, or models, or such other contribution as, in their opinion, under the circumstances of the case, may entitle the person to be enrolled as a Life Subscriber, or to enable him to resume his former rank in the Institution which may have been in abeyance from any particular cause. *The Council may, if they find good reason to do so, re-instate, under such conditions as they may see fit, any Member, Associate Member or Associate, whose name has been removed from the Register under the provisions of this Section.*

These cases must be considered and reported upon to the Council by a Committee appointed by the Council for the purpose.

APPENDIX,

CONTAINING FORMS REFERRED TO IN THE BY-LAWS.

FORM A.

A_____ B________ of________________________being upwards of twenty-five years of age, born on the ______ day of________ 18__, and being desirous of belonging to THE INSTITUTION OF CIVIL ENGINEERS, I recommend him, from PERSONAL KNOWLEDGE, as in every respect worthy of that distinction, because

[*Here specify distinctly the Qualifications of the Candidate according to the spirit of Articles* 2, 3, 4, 5 *and* 6, *Sect. II., and Article* 2, *Sect. III., of the By-Laws.*]

On the above grounds, I beg leave to propose him to the Council as a proper person to belong to the Institution.

Signed, (A. B.) *Corporate Member.*

Dated this___ day of____________18__.

We, the undersigned, concur in the above recommendation from personal knowledge, and being fully convinced that A. B. is in every respect a proper person to belong to the Institution.

Signed, (X. Y.) *Corporate Members.*

[*Undertaking to be signed by the Candidate.*]

I, the undersigned, do hereby promise, that, in the event of my election, I will be governed by the Royal Charters of the Institution, and by the By-Laws and Regulations as they are now formed, or as they may hereafter be altered, amended, or enlarged, under the powers of the said Charters; and that I will promote the objects of the Institution as far as may be in my power, and will present to the Institution an Original Communication, model, or scientific work for the library, within the space of twelve months from the date of my election.

Signed, ____________________

The Council, having considered the above recommendation, present A. B. to be balloted for as a ________ of the THE INSTITUTION OF CIVIL ENGINEERS.

Signed,____________________

Chairman.

Dated this____day of ________18__.

FORM G.

The Institution of Civil Engineers.

__________, 18__.

Sir,

I am directed by the Council of THE INSTITUTION OF CIVIL ENGINEERS to inform you that by a Resolution passed at a Special Meeting of the Council on the____ of________ they have, acting under the powers conferred upon them by Article 11, Section III. of the By-laws and Regulations of the Institution, ordered your name to be erased from the Register, and have declared you to be no longer a__________of the Institution.

I am, Sir, etc.

NOTE.—The remaining forms in the Appendix (except C, D, and H, which disappear) are unaltered, but are re-lettered to agree with the foregoing Sections.

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30 March, 1897.

JOHN WOLFE BARRY, C.B., F.R.S., President,
in the Chair.

(*Paper No. 3038.*)

"Electric Lifts and Cranes."

By HENRY WILLOCK RAVENSHAW, Assoc. M. Inst. C.E.

THE object of this communication is to direct attention to the electrical and mechanical problems which present themselves in the application of electric motors to working lifts and cranes; and to describe the methods by which they have been solved in particular cases which have come under the notice of the Author.

ELECTRIC LIFTS.

The simple gearing and slowly-moving mechanism necessary where hydraulic power is available afford many advantages. With the electric motor, however, the current varies with the work developed, while with the usual form of hydraulic motor the quantity of water used is as great with a light as with a heavy load. The greater simplicity of the hydraulic lift would therefore probably be an insufficient advantage to justify its introduction in places where electricity was already available, and where no hydraulic installation existed.

Motor.—The class of electric motor generally employed does not call for special description. Any good commercial machine can be used, a principal necessity being that it should require little attention. The machines should be sparkless under wide variations of load, the brushes self-adjusting for wear, and the direction of rotation reversible. The bearings should also be self-lubricating. The efficiency should be high at all loads; but a comparatively small machine can be used, as in most cases the maximum load is of short duration, the machine standing idle for at least half the time. Series motors have been used in some cases, but they are not suited for this work, as the speed varies excessively with a varying

load. Shunt motors are remarkably self-regulating, if the potential is constant, and they are now almost always used, series coils of a few turns being sometimes added to enable the motor to be started quickly and with a reasonable current. A distinctive characteristic of the electric motor is the comparatively high speed of rotation of the armature. It is possible to make a motor that will run at a very low speed, but the large size and heavy first cost of such a machine make it more convenient to employ a mechanical method of reduction.

Gearing.—In the earlier electric lifts, belts were generally used to transmit the power from the motor to the winding-drum, and in many cases the motor ran continuously. Reversing, starting and stopping were effected mechanically. This arrangement is, however, cumbrous, and positive gearing is now generally used—the motor being started, stopped and reversed as required. Double helical spur-gearing is perhaps the simplest and most efficient method of reducing the speed, but the noise inseparable from it prohibits its use in most places where lifts are required. Worm-gearing is more expensive and less efficient; but on account of its compactness and silent running it is almost universally adopted. The arrangement does not admit of wide variation. A quick pitch for the worm, ball- or collar-bearings to take the thrust, and the worm and wheel running in an oil-bath, form the principal characteristics. The older form of slow-pitched worm-gear had the advantage of being self-holding; but in an efficient worm-gear the wheel will drive the worm, so that no reliance can be placed on its holding power. When once the wheel and worm have worn themselves to a good bearing surface, the gear gives little trouble. The ball-bearings run well, if the ball-races are made of good steel and are ground true after being hardened. When ball-races are made of unsuitable materials and are not properly hardened the wearing surfaces become pitted, and much friction and noise occur. Notwithstanding the silent running of good worm-gear, a certain amount of vibration is always transmitted to the worm-wheel shaft; it is therefore usual to drive the rope-drum through intermediate pads of india-rubber, otherwise an unpleasant vibration is sometimes felt in the lift-cage.

The power is generally transmitted from the worm-wheel shaft to the cage by wire ropes wound on a grooved barrel. A modified arrangement, used by Messrs. Easton, Anderson and Goolden, is shown in Figs. 1–3, Plate 1. In this case, one end of each cage-rope is fastened to the balance-weight. On the shaft of the worm-

wheel is keyed a drum having twice as many grooves as there are ropes. The latter pass half round the drum over a guide-pulley and half round the drum again, the balance-weights being sufficient to give the necessary friction between the pulley and the ropes. A number of ropes on a high lift can thus be used with the advantage of a comparatively narrow drum.

The principal exception from the usual practice of reducing the speed by worm-gearing is the Sprague lift, which is extensively used in America. In it a screw is driven by the motor, directly or through gearing. Travelling on this screw is a nut which carries a pair of sheaves, over which the ropes pass in a similar manner to the ordinary hydraulic jigger. The nut forms virtually a ball-bearing, the balls returning through a race in such a way that they follow in a continuous stream. In the event of a ball jambing, the nut, which is held by friction-plates, revolves with the screw, and the travel of the lift is arrested.

Starting- and Regulating-Gear.—The driving-gear presents few difficulties, seldom showing variation from a uniform pattern. The requirements of the regulating-gear are:—Prompt starting, stopping, reversing, and ease of being worked by unskilled persons; absence of sudden jerks or jumps at starting, due to rushes of current; minimum current consumption, and regular speed with varying loads.

Automatic lifts are not largely used in Great Britain, a skilled attendant being generally employed, and the usual hand-rope adopted. A small reversing motor, or a pair of magnets or solenoids controlled by a switch in the cage, may be used to actuate the regulating-gear. The current has, however, to be carried from the cage, either by hanging wires or by sliding contacts; and where a rope is used the simplest arrangement is obtained. When a motor is running, the current in the armature is that resulting from the difference between the electromotive-force of supply and the back electromotive-force of motor. If the machine is switched on, while it is standing, there is no back electromotive force, and the current is that due to the full electromotive force of supply, the resistance of the armature and circuit being constant. As in a good motor the back electromotive force is only about 5 per cent. less than that of the supply, the current, on starting without added resistance, would be nearly twenty times as great as the working current, being practically equivalent to a short circuit. This would cause a great fluctuation in the supply electromotive force in the adjacent circuits and an enormous turning effort in the motor, causing it to start with a jerk. Indeed, the fuses would be melted,

as such a rush of current would be dangerous, and could not be tolerated. In order to start smoothly and without a great rush of current, resistance must therefore be inserted in the motor circuit. It is usual to provide a switch so arranged that a resistance is inserted in series with the armature. This resistance allows only sufficient current to flow to enable the motor to start, and is afterwards cut out by a further movement of the switch-handle. The switch is sometimes worked entirely by the attendant, who switches on slowly, giving the motor time to start. With a lift in which a hand-rope is used, there is no indication of the position of the switch, and an unskilled person might suddenly switch out all the resistance, causing almost as great a rush of current as if there were no resistance in use. Various arrangements of dashpots have been used to prevent the rope from being pulled suddenly down; it should, however, require a very small effort to work it, and an arrangement which automatically cuts out the resistance is more satisfactory. The following arrangement has been adopted by the Otis Elevator Company. When the hand-rope or other starting-gear is actuated, the current is switched on in the right direction, and the brake is released; a switch arranged to automatically cut out the resistance is also released by a cam, but its action is retarded by a dashpot and a solenoid, which does not release the switch until the current has fallen below a certain limit. This has been largely used, and works well. Another form of gear designed by the Author is shown in Fig. 2, Plate 1. It consists of a centrifugal governor driven from the motor-spindle, and controlled by a spring, so that the travel of the switch which it actuates is nearly proportional to the speed of the motor. This switch is arranged to decrease the resistance in the main circuit as the speed of the motor increases, all the resistance being cut out just before the motor attains its maximum speed. Sufficient resistance is inserted to allow the motor to start with its maximum load; but if the motor is over-loaded or any of the gear is jammed, the resistance is not cut out, and only the ordinary starting current continues. When fitted with this starting-gear, an electric motor behaves in almost exactly the same way as a steam-engine, and is specially applicable to winches and cranes, as it is impossible to overload the machine. A similar gear has been used by Messrs. Siemens and Halske.[1]

When lifts are supplied with energy from a central station, the authorities generally specify that current shall not be switched on

[1] Minutes of Proceedings Inst. C.E., vol. cxxv. p. 515.

in steps of more than, say, 10 amperes. The reversing-switch, which is driven by a hand-rope, is therefore generally fitted with a certain number of resistance contacts, if the starting-current for the motor exceeds the specified limit. This resistance is also of use with fast-running lifts, where unskilled persons are liable to hold the rope too long and reverse the motor suddenly. The governor-gear, however, in such a case at once promptly inserts the resistance. A gear having an almost similar effect has been designed by the Author. It consists of a solenoid, wound with fine wire and connected across the brushes of the motor. This actuates a resistance-switch and is controlled by a spring or weight. When the motor is standing, only a minute current flows through the solenoid; but directly the motor starts, the potential at the brushes increases and causes the solenoid to gradually cut resistance out. This gear is convenient in some cases, but has the disadvantage that current is always flowing through the solenoid while the motor is running, thus diminishing the efficiency of the system.

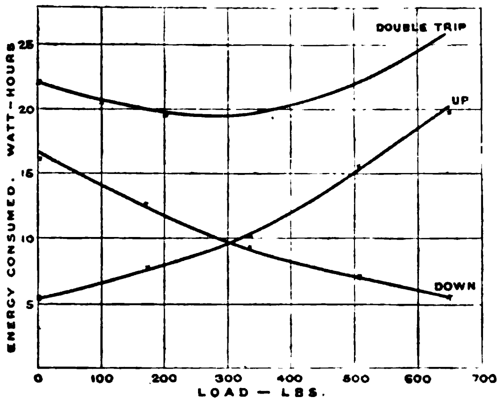
The Brake.—It is important that a lift should stop promptly when required, and some form of brake is always employed. This may be worked from the hand-rope, but an automatic magnetic brake is generally used, it being important that the rope should not require much effort to work it. For this purpose the ordinary bar electro-magnet is generally adopted, as a magnet of reasonable dimensions can be made to give a pull of 1 ton through a distance of ½ inch. The magnet can be arranged to release the brake when the current is switched on, the cage being automatically stopped when the circuit is purposely or accidentally broken. For this reason the magnetic is far safer than the mechanical brake. The shunt coils of the motor and the magnet are controlled by the starting switch, a resistance, wound to have little self-induction, being fitted to prevent sparking when the magnet-circuits are broken. This resistance is inserted by the switch just before the magnets are cut off, and is left in circuit with them while they remain disconnected. The Author's usual practice is to make this of the same resistance as the magnet-coils with which it is connected. By this arrangement the circuit of a magnet weighing several tons can be broken without an injurious spark.

Indicator.—Although the main current may be switched off, the hand-rope can be left in such a position that the brakes and field-magnets are still in circuit. In the lifts designed by the Author an electric vibrator or "buzzer" is connected in parallel with the field magnet-coils, a large resistance being inserted to prevent

waste of current. A visible indicator can be used if the noise of the buzzer is objected to. An indicator should always be fitted to prevent accidents and waste of power.

Tests.—By the courtesy of the Otis Elevator Company, the Author has been able to carry out tests of an electric lift erected by them, the particulars of which are given in Appendix I and in *Fig. 4*, which show the relation between the energy consumed and the cost of working with various loads. The height through which the lift travelled was 36½ feet. The cost of working is lowest at about half-load, the cage and load being almost exactly

Fig. 4.



Otis Lift—Curves showing Energy Consumed at different Loads.

balanced. This lift was new, and would perhaps give better results after working for some time; it may, however, be taken as a fairly representative example of its kind.

Electric Cranes.

Cranes driven by electric motors are coming into frequent use, the ease by which the power can be transmitted to the movable framework of a travelling or jib crane, and the adaptability and compactness of the electric motor presenting many advantages over other forms of mechanism. In the case of a travelling crane the current can easily be collected from conductors stretched along the walls or gantry supporting the crane. These require no attention when properly fixed, and are preferable to fast-running ropes or square shafts which are running continuously and waste much power. Where electricity is used for other purposes there

is little loss of power while the crane is standing, as in those cases where separate motors are used for each motion they are stopped, started and reversed as required. Where mechanical methods of control are employed, the motor must naturally be running idle for a large part of the time, but even in this case the attendant can start and stop it when it is not required.

The use of a separate motor for each motion appears at first sight to present many advantages. The power can be applied to the work in the simplest manner, all clutches being dispensed with, and smooth starting, regulating and reversing are obtained. On the other hand, with a single motor, the electrical details are of the simplest kind, and the rush of current, which is almost certain to occur at starting with a careless driver, is avoided. The subsidiary motions absorb so little power compared with lifting that the designer often prefers to use simple friction-clutches, which are understood by an ordinary mechanic, to the more complicated and often unmechanical electrical gear. There seems little to choose between the two systems, both of which are largely used with good results.

By the permission of the authorities at Woolwich Arsenal, and of Messrs. Easton, Anderson and Goolden, the Author is enabled to give, Appendix II, the results of a series of tests of a 20-ton electric crane, Figs. 5–8, Plate 1, the electrical contrivance of which was designed by him. This crane was erected as an auxiliary to the large radial steam-crane in use in the annealing shop at Woolwich Arsenal. It consists of a radial girder supported at the inner end by a cast-iron belt which encircles the upper part of the centre column supporting the steam-crane. The belt is free to rotate, being carried on coned supporting wheels which run on a circular race bolted to the column. The outer end of the girder is supported by a vertical leg, built of lattice girders, carrying the chain-barrel, electric motor and driving gear. The leg rests on two two-wheeled bogies, the wheels running on a single circular line which is also used by the steam-crane. The mechanical details of this crane were designed by Mr. C. H. Moberly, M. Inst. C.E.; the Author, however, proposes to describe here only the details of the electrical gear.

The current is supplied from the electrical central-station at the Arsenal, at a potential of about 310 volts. The cables are carried up one of the legs of the centre column, and are attached to two collecting-rings fixed on insulators upon the lower part of the race which supports the revolving belt, Figs. 7. These collecting-rings are made of lengths of copper strip, 2 inches

by $\frac{15}{16}$ inch, and, being bent to the correct curve, are fixed by countersunk bolts to small gun-metal blocks, screwed on to the ends of horizontal Aetna insulating bolts. The fixing for these bolts is shown to a larger scale in Figs. 8. The insulators consist of gunmetal bolts screwed at one end and covered for nearly the whole length with a hard fibrous material, giving excellent mechanical support with remarkably good insulation. The insulation-resistance of the cables inside the crane-house, including the collecting-rings and collectors, was found at the time of the experiments to be about 5 megohms—an excellent result considering the atmosphere of steam and dirt in which the crane was working. The current is collected from the rings by gunmetal plungers, $\frac{7}{8}$ inch in diameter, fixed on insulating blocks to an arm bolted to the radial girder. The plungers have a range of more than $\frac{1}{2}$ inch, to allow for unevenness in the rings, and have flexible strips fixed to their outer ends by which the current is carried to the terminals to which the cables from the motor are attached. This arrangement of collectors and rings is shown in Figs. 8. The cables are carried along the girders to the main switch at the foot of the vertical leg. Fixed to the vertical girder is a large circular switch of solid construction, having a number of contacts connected with iron-wire resistances, capable of carrying the working current of the motor without over-heating. An ampere-meter and volt-meter are fixed above the switch. One motor only is used; it is shunt wound, with a drum armature and carbon brushes, and runs at about 900 revolutions per minute at 310 volts. There is no sparking at the brushes with varying load, and little attention is required. The shaft of the motor is coupled direct to a worm-gear by a shaft 4 feet long, large enough to take the torque, but small enough to compensate for any want of alignment between the motor and the worm-shaft. This arrangement works well, and, having no back-lash, is preferable to a flexible coupling. The worm-gear mentioned consists of a treble-thread steel worm, gearing into a worm-wheel, having fifty-one teeth of 2-inch pitch, the reduction being in the ratio of 17 to 1.

The direction of rotation being constant, a simple thrust-bearing is employed, consisting of a number of hardened-steel lenses. This was considered to be more suitable than a ball-bearing for so large a power, as the motor is only used at full power for a few minutes at a time. On one end of the worm-wheel shaft is fixed a spur-wheel, which transmits the power through a train of gearing and reversing friction-clutches to the travelling and radial motions.

On the other end of the worm-wheel shaft is a bevil-wheel, which actuates the winding-barrel through a friction-clutch and two-speed gear. A self-acting brake is connected to the chain-barrel by pawls and a ratchet-wheel automatically holding up the load, lowering being effected by releasing the brake.

Owing to the special requirements of this crane, and the fact that it was advisable for the attendant to have ready access to the motor and gear, a good deal of gearing was used, and the power was applied in a somewhat indirect manner. In consequence a chain-block, weighing nearly 2 tons, was used. This weight causes a considerable reduction in the efficiency at light loads; but the loss is easily ascertained, and the ratio of the electrical energy consumed to the work developed in lifting the load, with the falling block, is given in Appendix II. Although it was not possible to test the particular electro-motor used, a Table of efficiencies is given of a machine almost identical with it in size and construction, and the estimated power absorbed is shown. The efficiencies may certainly be taken as correct within 1 per cent.

With no load on the hook, the weight on the inner race was 14 tons, and on the outer line 46½ tons, the total weight being 60½ tons. During the tests the load was suspended from the middle of the girder, the weight being equally distributed between the ends.

The Paper is illustrated by eight tracings, from which Plate 1 and the *Fig.* in the text have been prepared.

[APPENDIXES.

APPENDIXES.

APPENDIX I.—Tests of an Otis Electric Lift at 12 Hill Street, W., 27th November, 1896.

No. of Test	1	2	3	4	5	12	7	8	9	14	15	18
Direction	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down
Load . . . lbs.	648	648	506	506	336	336	171	171	0	0	336	336
Travel . . . feet	36·5	36·5	36·5	36·5	36·5	36·5	36·5	36·5	36·5	36·5	24·75	24·75
Time per trip seconds	28·0	22·0	25·0	21·0	22·0	23·0	22·0	22·4	22·0	24·0	16·4	16·0
Maximum current amps.	13·0	11·0	12·0	12·0	11·0	12·0	10·0	11·0	12·0	12·0	12·0	12·0
Average „ „	11·5	3·0	8·5	4·0	6·5	6·5	4·25	7·5	2·5	9·5	6·5	5·5
Duration of current seconds	28·6	23·2	27·2	23·2	25·2	24·0	24·0	24·2	23·4	25·8	17·6	16·4
Energy per trip watt-hours	19·8	5·6	15·6	7·08	11·2	9·27	7·8	12·68	5·37	16·35	8·3	6·83
Cost per single trip at 4*d*. per unit . . .	0·079	0·0225	0·0624	0·0283	0·0448	0·037	0·0312	0·0509	0·0214	0·0655	0·0332	0·0273
„ „ double trip .	0·1015		0·0907		0·0818		0·0821		0·0869		0·0605	
Average current from meter reading amps.	12·2	4·25	10·2	5·4	7·9	6·9	5·75	9·20	4·0	11·2	8·3	7·4
Average speed feet per minute	78·0	99·5	87·5	104·0	99·5	95·0	99·5	98·0	99·5	91·0	90·0	92·7

APPENDIX II.

Tests of a 20-ton Electric Radial Crane at Woolwich Arsenal, 17th March, 1896.

Hoisting.

No. of Test . . .	15	16	17	18	19	20	21	22	23	24
Gear	Slow	Slow	Fast	Fast	Slow	Slow	Fast	Fast	Slow	Slow
Net load on hook, tons	0	0	0	0	9	9	9	9	20	20
Gross load, including block tons	1·83	1·83	1·83	1·83	10·83	10·83	10·83	10·83	21·83	21·83
Speed of hoist feet per minute	16·36	16·36	34·35	34·35	15·79	15·79	30·40	31·03	13·84	13·84
Average potential volts	306	306	300	300	298	295·5	285	282	267	270
" current amps.	18	17	26	25	49·6	49·3	100	100	98·3	101·6
" work E.HP.	7·38	6·97	10·45	10·05	19·81	19·53	38·21	37·80	35·18	36·77
Net HP. delivered to load . . .	0	0	0	0	9·64	9·64	18·56	18·95	18·79	18·79
Gross HP. delivered to block	2·03	2·03	4·26	4·26	11·60	11·60	22·33	22·81	20·50	20·50
$\frac{\text{Net HP.}}{\text{E.HP.}} \times 100$.	0	0	0	0	48·66	49·35	48·58	50·13	53·42	51·11
$\frac{\text{Gross HP.}}{\text{E.HP.}} \times 100$	27·51	29·14	40·79	42·42	58·61	59·45	58·45	60·36	58·28	55·76
Estimated losses in motor, in HP.	2·80	2·80	2·84	2·84	3·01	3·01	3·68	3·68	3·55	3·62

Efficiency of Electric Motor.

HP. at shaft . . .	48	36	24·0	12
Efficiency, per cent. .	92	91	88·5	81

Circular Travel.

No. of Test	53	54	55	56	57	58
Load on hook . . tons	Light	Light	9	9	20	20
Speed at racer, feet per minute	55·0	55·0	55·0	55·0	54·0	54·0
Potential. . . . volts	308·0	312·0	307·0	310·0	300·0	297·0
Current . . . amperes	15·3	15·0	19·3	18·0	19·0	21·0
Work . . . . E.HP.	6·3	6·3	7·9	7·5	7·64	8·4

Radial Cross Traverse.

No. of Test	79	80	81	82	85	86
Load on hook . . tons	Light	Light	9	9	20	20
Speed of carriage, feet per minute	33·7	33·45	33·45	33·45	32·27	32·4
Potential. . . . volts	307·0	308·0	302·0	305·0	287·0	282·0
Current . . . amperes	12·4	13·0	18·75	19·3	26·8	27·0
Work . . . . E.HP.	5·1	5·36	7·6	7·9	10·3	10·2

Discussion.

Mr. Wolfe Barry.

Mr. J. Wolfe Barry, C.B., President, thought this was the first time a Paper had been read before the Institution on the application of electricity to such mechanical contrivances as lifts and cranes, and it appeared to mark an era of considerable interest. The application of hydraulic power to lifts and cranes had been so universal for so many years, and had been so extremely successful, that it would be very interesting to have some definite comparison both of first cost and of the cost of working between hydraulic and electrical gear. He was sure that to many members, who had to advise on the application of power to large enterprises, the matter dealt with in the Paper would be found of great interest. He might mention that only recently, in Paris, he had seen a hydraulic lift being taken out of an hotel and an electric lift substituted; and he was told it was by no means a solitary instance. He thought the members would find plenty of food for discussion in the Paper, and he would be only speaking their sentiments when he offered a hearty vote of thanks to the Author for having brought the subject before them in so able a manner.

Mr. Adamson.

Mr. Daniel Adamson, of Hyde, remarked that for lifts, Messrs. Joseph Adamson and Company had been accustomed to use a shunt-wound motor with additional series coils, as mentioned by the Author; but it was found that when high speeds were required, the conditions of running the motor with additional series coils were such that a varying load gave a variation in the speed, which affected the momentum of the moving cage, so that when it was stopped it travelled further, against the resistance of the brake, sometimes than others, and missed the landing. He had overcome that difficulty by arranging the automatic switch to cut out the series coils after cutting out the resistance; thus the motor ran at a fairly constant speed after starting. With regard to travelling cranes, the three-motor type had been preferred, the series motor being always used, on account of its greater starting-power, and also its characteristic—which was an advantage in that case—of running faster under lighter loads. It also enabled the change of gear, for giving a higher speed with lighter loads, to be dispensed with. In connection with the lifts, the arrange-

ment they had used for cutting out the resistance was to connect the sliding-switch with some moving portion of the mechanism, so that as the motor started it gradually cut out the resistance. This was found to work well, and was much simpler than either of the arrangements mentioned in the Paper. As to choice between single and separate motor-cranes, his opinion was, he thought, confirmed by practice in the United States, where greater attention appeared to be paid to the matter than in England. On the occasion of his last visit, he noticed that Messrs. Sellers of Philadelphia, who had first advocated the one-motor crane, had begun to make cranes of the three-motor type. He did not hear of any makers of three-motor cranes commencing to make a single-motor crane. The principal reason for preferring the three-motor crane was the reduced wear and tear on the mechanical portion, owing to the fact that, even when the crane was nominally in use, there was a considerable amount of idle time, as, for instance, when adjusting the chains. During those intervals, when the crane was not actually hoisting or travelling, with the three-motor crane the mechanism was at a stand-still; whereas in the single-motor crane, or in any other type of power-driven crane, some portion of the mechanism was running, and there was thus wear and tear, varying with the type of crane. The maintenance of clutches and such arrangements for mechanically controlling power was very costly. He called to mind an example of a steam-driven crane, in a girder-yard in which the square cross-shaft was used to transmit some of the motions, which lasted 11 weeks, so that four were required in the year. Another advantage of the three-motor crane was that, each motor being fitted with starting resistance, the man working it was able to start very gradually; and, in case he wanted to travel only a small distance, that was a great advantage; with other kinds of power-driven cranes it was much more difficult to travel a short distance and stop again with precision. Cases also arose in which the motion was required to run slowly for a short time, as when drawing patterns. That was not so easily effected with a clutch or strap-driven crane. The switches of their first three-motor crane had lasted just two years, at the end of which time they were taken down to be refaced and replaced. Progress had since been made, and no doubt the switches now made embodied considerable improvements, but how much was a matter for time to prove. The only results given by the Author had reference to tests of a crane of an unusual type. He noticed that the efficiency came out quite as high as in some of the tests he had made 12 months ago, with five over- Mr. Adamson.

Mr. Adamson. head travellers. In those cranes the speed-reduction between the motor and the hoisting barrel was effected by means of three sets of spur-gear, two of those sets having machine-cut teeth; whereas in the arrangement shown in the Paper, Figs. 6, Plate 1, the motion was transmitted through a worm-wheel, a bevil gear, and two sets of spur-gear. This should not be such an efficient arrangement as the three sets of spur-gear mentioned; yet the efficiency appeared as high as he had obtained. His tests, however, had been made when the cranes were comparatively new, and possibly better results could be obtained now. Still, his experience, judging from other tests he had seen, was that the efficiencies stated were high. He would ask the Author to give details as to the method of taking the measurements, and also as to the care taken to see that the instruments were accurate.

Mr. Ellington. Mr. E. B. Ellington thought that, notwithstanding the progress of the past 15 or 16 years, in its application to hoisting, electricity was, as he had pointed out in 1881,[1] subject to the same defects as steam, gas, and compressed air. When electricity or any of the other powers were applied to lifting, dependence had to be placed, first upon the brake, secondly on gearing, and thirdly on various controlling mechanisms. All those things were avoided by the use of hydraulic power. A simple valve sufficed to control all the motions; no brake was required, and practically no gear. A diagrammatic illustration of a complete hydraulic lift, the ram, the cylinder, and the supply-pipe, was given in *Fig. 9*. The whole machine might be said to be a modification of the supply-pipe. That apparatus, with the addition of a simple valve, controlled in the ordinary way, formed as perfect a type of lifting machine as it was possible to conceive. The only objection the Author had stated to the use of the hydraulic lift was that it was not economical. That type of lift, *Fig. 9*, was necessarily an uneconomical machine. Not only did it require the same power for a light load as for a heavy load, but, from the nature of the case, the useful load was only a small proportion of the total load. That was the perfect type of lift from the mechanical point of view, apart from economy. The

Fig. 9.

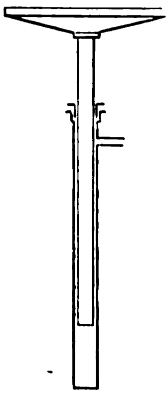


Diagram of the Direct-Acting Lift.

[1] Proceedings of the Institution of Mechanical Engineers, 1882, p. 122.

next step was the introduction of multiplying gear. *Fig. 10* showed the ram and the cylinder, and, with the addition of the cage, a suspended lift, in which the chains or ropes were introduced. In that machine, the ideal simplicity of the first type was departed from and its relative economy increased. The economy of that second type of lift was limited by the fact that it required the same power to raise a light load as it did to raise a full load. To that extent he agreed with the Author. From the earliest times, nearly 50 years ago, when introduced by Lord Armstrong, it was seen, however, that greater economy might in many cases be advantageously obtained by dividing the rams into two, three, or more, by suitable mechanism. In the two machines he had described there was a condition of things which was *sui generis*—altogether different from the application of any other power to lifting. But it was not necessary to use those types of lifts when employing hydraulic power. A hydraulic engine could be used and fitted with the Hastie gear which automatically adjusted the throw of the crank when there was almost perfect adjustment of the hydraulic power used to the load. But, although a greater economy was secured, a more or less complicated mechanism was introduced. No brake or other controlling details had been introduced, but the machine had been complicated. But it was not necessary to use a hydraulic engine at all; in a properly adjusted turbine perfect control was secured, as well as economy resulting from the adjustment of the power used to the load lifted, but the troublesome and often dangerous details necessary when using steam, gas and electricity, such as had been depicted in the Paper, had to be resorted to. There was no controlling power apart from the brake. Owing to their great simplicity a large number of the first type of lifts he had described, *Fig. 9*, were in use. They, no doubt, would continue to be employed where practicable for all lifts of only 10 feet to 20 feet, notwithstanding their relative large consumption of power. He now wished to consider in more detail the question of economy. In the Mr. Ellington.

Fig. 10.

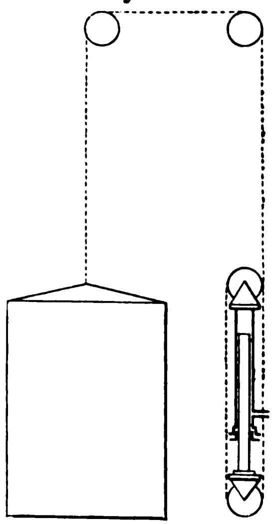


DIAGRAM OF THE SUSPENDED LIFT.

Mr. Ellington. Paper to which he had alluded, particulars would be found of a trial of a lift which was commensurable with the Otis electric lift. The load lifted in that case was 886 lbs., with 790 lbs. pressure on the square inch. The multiplying power was 10 to 1, the height of the lift being 71 feet 8 inches, so that it was not so economical as it would be if it had been made for a height of 36 feet as given in the Table. The quantity of water used would be 6 gallons for the 72 feet, and 3 gallons for the 36 feet. Using for the purpose of discussion electric units, units of energy, it would be found that the cost of 3 gallons at 4*d.* per unit, the standard taken by the Author, worked out at 0·078*d.* for each double journey. This cost was lower than the lowest cost of the electric lift, even when there was no work being done by the lift up or down; the figures were 0·082*d.* as against 0·078*d.*, notwithstanding the fact that there was an increased load in the hydraulic lift of over 2 cwt. If the load were reduced to the 648 lbs. mentioned in the Table, by reducing the area of the rams by the amount required, with an efficiency of 100 per cent. for the additional 2 cwt., the quantity would be $2\frac{3}{4}$ gallons, and the cost would be 0·071*d.* As a rule, lifts were not worked with a full load or the full height. If they ascended with a full load, they did not descend full, but generally with only the attendant. Therefore a proper comparison was to take the lift, worked at half-load up, and down with the attendant two-thirds of the height. Under those circumstances, using the Author's Table, he found that the cost would be 0·072*d.* in the case of the electric lift; and that the cost of the hydraulic lift, the particulars of which he had given, was 0·048*d.*, or 18 watt-hours, and 12 watt-hours respectively, a difference of 50 per cent. It was true that a simple hydraulic lift took exactly the same power at all loads, but it took with a full load less than the electric lift with the lightest load, according to the Table. There was nothing in the question of economy, because the hydraulic machine was so extraordinarily economical at full load that the work could not be done more cheaply at any load. So economical an electrical machine was not available, even with the advantage due to the fact that there was no variation of power according to the load in the hydraulic lift. If mechanism was introduced which would reduce the work done in proportion to the load, there would be still further economy in the use of hydraulic power. With regard to the cut-out resistances, he might mention that a year or two ago he had examined some electric lifts in Berlin, where there were a great many at work on the electric mains, and he was much struck

by the peculiar action, which at first he could not account for. For instance, a lift hoisting about 10 cwt. worked well with a load of three persons under the action of the pulling of the rope by the attendant; but with full load it was several seconds after the rope was put into the position for lifting before the lift moved. That was very dangerous, and he hoped that the matter would be fully explained. As far as he could see from the Paper, that difficulty existed in the machines described, viz., that the current could not be applied directly, but time must be given. There was an automatic cut-out arrangement, which took a certain time while the current was being switched on, and that was liable to lead to accidents. When passengers entered a machine, expecting it to move on and it did not, the first thing they did was to try and get out. At the Allgemeine Elektricität Gesellschaft's works also, where everything was done by electricity, and three-phase motors were used, he was shown the traveller going about 120 feet, lifting four or five times. He was asked to work it, that he might see how easily it was manipulated. He started to work it as he would any other crane or any hydraulic crane, but the machine broke down and failed to move. He was informed that he must apply the current much more quietly, and had to wait 5 minutes before it was put to rights again, and the same difficulty of control was experienced. He thought the proper application of electricity to the purposes of lifting was indicated by what he had said as to the necessity of complication when endeavouring to realize high economy. There were many cases in which hydraulic power was supplied by hydraulic engines. When a hydraulic engine or a turbine was used, it was a fair question whether electricity or hydraulic power was the better. He thought there was confusion in the Paper as to the terms "travelling crane," and "traveller." He understood by a "traveller" what the Author had described as a "travelling crane," moving a long distance. For "travellers" he believed electricity was the proper power to use. In timber-yards he thought it was the best kind of apparatus that could be used. The fact was that electricity was splendid for traction, but where energy was required for lifting only, hydraulic power was better. Mr. Ellington.

Mr. F. S. COURTNEY thought that for a lift of short stroke, where hydraulic power was available, it should be used; but for a long stroke electric power had advantages. In the starting of an electric lift there was a large increase of current beyond that necessary when once the lift was running, and this became a con- Mr. Courtney.

Mr. Courtney. siderable factor in short journeys. In Appendix I, taking the tests of this electric lift as representative of any other electric lift under similar conditions, he found that with full load the starting current was 13 amperes, while the running current was 11½ amperes; with a light load the starting current was 11 amperes, and the running current 7 amperes. With so short a stroke as only 26½ feet, the larger current at starting told materially on the mean current used for the complete journey, whereas with a longer stroke the percentage of increase due to starting was materially diminished. With the electric lift there was the advantage that the amount of current varied in proportion to the work to be done, and this, with varying loads, was a strong point in favour of electric power. There were differential hydraulic lifts, which gave greater economy in water-consumption than the single-acting lift; but they began to lose somewhat in efficiency, and they also required more attention. The question then arose whether the attention necessary for a differential hydraulic lift was materially less than that in an electric lift; he did not consider that this was so. The electric lift certainly could be made to work under perfect control. With shunt-wound motors, with a series starting-coil, they started smoothly, and they could be regulated to stop at the landing-stages without jerks, so that in that respect they could compare with the best hydraulic lifts. There was in the electric lift a high-speed dynamo, and care was necessary in the reduction of the gearing to render it sufficiently noiseless to be placed in positions where it had frequently to be placed, such as in the centre of a staircase and the like. With ordinary gearing it was difficult to do away with the noise, but with worm-gearing this might be done effectively. He did not agree with the Author that it was difficult to have worm-gear running without vibration, as there were lifts with worm-gear which were running without any vibration in the cages, and working quite smoothly. The question of ball-bearings had been alluded to by the Author for small lifts; where the load on them was light a very high efficiency could be derived from them. But there was very much greater difficulty in getting the balls evenly tempered and absolutely to gauge, than there was in making a true running path. He would venture to sacrifice the little difference of efficiency that there might be between a good thrust-bearing and a ball-bearing for larger lifts, in order to get the greater simplicity in the thrust-bearing. Their extreme adaptability to standardizing also commended electric lifts from a manufacturer's point of view. The length of stroke did not enter

into the element, so far as driving gear was concerned. The motor had simply to be run so much longer, and the increased length of stroke was obtained; whereas with the hydraulic lift it became necessary either to increase the length of stroke of the ram or increase the number of multiplying sheaves. It was essential in an electric lift that the controlling arrangements should be precise, and it should be possible to stop the lift absolutely at its proper level; because if they did not, and stopped a little short of the landing-stage and had to start again, that excess of current, which was unavoidable at each time of starting, recurred. Those were points which only had to be realized to be mastered, and in practice there was little difficulty in controlling the lift so that it could stop precisely where required. With regard to the electric crane described in the Paper, that was an adjunct to an existing crane, and therefore there was more gearing about it than would have been the case had it been a complete design, and its efficiency was to a certain extent sacrificed. In his own works there were two electric cranes, one of 15 tons, and another of 20 tons, which had been running regularly 9 years and 8 years, and worked without the slightest trouble either in the electrical or mechanical parts. Mr. Courtney.

Mr. T. D. Hollick observed that the gear for which he was responsible, a view of which the Author had thrown upon the screen, gave, when used on electric cranes, much higher results than those of the crane described in the Paper. The crane which had been exhibited had an efficiency of 74 per cent., as compared with 53 per cent. It was tested under ordinary conditions; the weight of the hook had not been subtracted and there was about 150 feet of wiring. Those results had been obtained, not by increasing the electrical efficiency of the motor, but by increasing the efficiency of the gearing—the mechanical arrangement between the motor and the load. With regard to lifts, the Author's tests showed an efficiency of about 20 per cent. or 25 per cent., and that the cost per ton raised 36·5 feet was 1·015*d.*, the price of the current being 4*d.* per unit. That was a high cost per ton, but he would expect to find a high price when the efficiency of the lift was considered. In the case of the lift the losses probably took place between the motor and the load. With regard to the efficiencies of the cranes, the crane described in the Paper lifted 20 tons 15 feet per minute, whereas the crane which had an efficiency of 74 per cent. lifted 6 tons 15 feet per minute. The motors in each case ran at about the same speed, and the load was raised at about the same speed; therefore there was the same reduction of speed Mr. Hollick.

Mr. Hollick. between the motors and the load. He thought the Author would have secured a higher efficiency had he used his arrangement in that position. The current capable of raising 6 tons 15 feet per minute was about 31 amperes; there was no rush of current at starting, as had been mentioned by some of the speakers. The variation during the run was about 2 amperes, probably due to inequalities in the gearing, the spur-gearing, the rope or barrel, but there was not a large jump at starting. The recording amperemeter was checked with an ordinary meter, and the results gave about 74 per cent. efficiency. He did not agree that electric cranes were inferior to hydraulic cranes, on the three grounds of efficiency, simplicity, and finality. In the matter of efficiency, the hydraulic cranes and lifts had about the same efficiency as those mentioned by the Author, which would be about 50 per cent. With regard to the 74 per cent. efficiency, that, he thought, was a fair average test, though higher efficiencies had been obtained. It was taken in the ordinary way of work and exceeded that of the hydraulic cranes. The question of simplicity, however, was more difficult to deal with; it appeared to be more a matter of opinion. If there were switches with resistance and such complications, it followed that the apparatus appeared complex. But he thought that if a shunt-wound motor, with a simple mechanical gear like that which he had arranged, were compared with an ordinary hydraulic arrangement, say with a series of cylinders in order to increase the efficiency at the smaller load, it would be found that the simplicity was in favour of the electric gear. It should be remembered that in all those matters people had become used to hydraulic cranes; they had been in use for perhaps 40 years, while, on the other hand, electric cranes were new. He already knew many instances in which employers had become used to the electric cranes. The cases in which they had not become used to them were generally those in which the cranes were not applied properly, or the switching arrangements were complex. In the crane he had referred to, the switching arrangement was most simple. Anyone could switch it on, and it was impossible to fail. In regard to finality, he did not think there was such a thing, especially in the case of machines having an efficiency of only 50 per cent.

Mr. Walker. Mr. F. W. Walker thought the simplicity of hydraulic machinery was even greater than had been pointed out by Mr. Ellington; and he did not think the direct-acting hydraulic hoist would be more wasteful than an electric one. It was assumed by Mr. Ellington that the direct-acting hydraulic hoist would only

Mr. Walker.

be a ram and table or cage—the ram working in a cylinder; therefore the ram would have to lift the moving parts before it lifted the load. If the electric hoist was allowed a wire-rope or chain, he wished to know why a hydraulic hoist might not be allowed the same privilege. He submitted that if the hydraulic hoist with a direct-acting ram had wire-ropes from the top of the cage, or from the corners of the cage, connected with balance-weights, such a direct-acting hoist could be made to work more economically than an electric hoist. His firm were in the habit of making coal-tips, where 20-ton wagons were continually lifted, not with the expense of water necessary to lift a 20-ton coal wagon, in addition to the weight of the moving parts; but the moving parts, either by hydraulic cylinders in constant communication with the accumulator, or by balance-weights in connection with wire-ropes or chains, were balanced within about 2 tons of the total load to be lifted; therefore the hydraulic power only had to lift the actual coal, the wagons being a constant quantity. It was not fair to compare the two things, unless on parallel lines, and he submitted that if the hydraulic hoist was allowed to have a wire-rope, and then to add its own power in its own way, it was simply a plain cylinder and a ram, which was not only worked much more safely and simply, but more economically than any power which could be applied to it by an electric motor. The jiggers referred to by Mr. Ellington consisted of a cylinder which did not require attention, a ram and a gland. In addition there were two pins, one at the top and the other at the bottom, with a number of sheaves working on them. In machinery of that kind, the smallness of the number of working parts was of immense value, not only because it made the machine work better, but also because it made it easier to keep in repair. The fact that it could be controlled and worked by much cheaper labour was an additional advantage of hydraulic machinery. He thought results as to the question of relative economy would be of great value, because economy, first in capital outlay, secondly in maintenance, and thirdly in working, was of primary importance. He hoped that some manufacturer of electrical plant would give the Institution the benefit of his experience and state not in electrical terms, but in plain old-fashioned horse-power or foot-pounds, how much it cost to generate the power, and how much was lost when it was used. In dealing with such a question, which was influencing large dock- and railway-companies in the consideration of the machinery they were to employ, that subject should be settled

Mr. Walker. once and for all. How much did the power cost to produce, and how much was produced and then wasted? He thought it would be generally admitted that if electrical power was to be utilized in large installations such as docks and railways, it must be used in some way by which it could be stored. He thought it would be impossible to drive direct the machinery at the Bute or the Barry Docks, or at the North Western, or the Midland, or any other large railway company's works. In one dock at one minute there would be twenty coal-tips working as hard as they could, and the next minute perhaps, when the dinner-signal was given, hundreds of horse-power suddenly disappeared. He should like to know what an electrical engine would do with this power? A hydraulic engine put it into the accumulator and used it after dinner. He did not know what an electric engine would do with it; was it to stop instantaneously? Was the man always there ready to stop it, and what was going to happen if some industrious tipper went on working and still required power to work the machinery? That was the great problem which should be dealt with clearly and distinctly. With regard to accumulators, he did not think that the value of the hydraulic accumulator, indeed, its absolute necessity on a dock, was generally understood. In some docks there might be pumping-engines with 1,000 HP. continually at work; but in addition to that there would be hydraulic accumulators in all parts of the dock, storing many thousands of HP. which, when twenty coal-tips and fifty capstans and thirty cranes and the dock-gate machinery all required to be moved at the same time, would be supplied by those accumulators. He wished to know whether there was any arrangement by which electrical machinery could accomplish the same results. As to the general working, he should like to ask if it did not require much more skilful labour to keep it in order, and if it did not cost very much more, also if the difficulty of working it either slowly or quickly at pleasure was not much greater? Could an electric crane be worked when picking up the loads slowly, and when it had felt the load let it shoot up at 300 feet a minute? Could the operator lower it at no cost, or was it necessary to work the machinery? When lowering, had the operator only to let loose the handle in order to stop it? That was all that was necessary with a hydraulic arrangement. Could all that be done with equal simplicity in the case of an electrical motor?

Mr. Unwin. Mr. P. I. Unwin desired to refer to results as to the working cost of passenger and goods lifts, and of machines similar to those used in hotels, warehouses, private houses, and other high build-

ings, in London and other great cities. Hydraulic lifts had been well known for many years, and they had been brought to a high pitch of excellence. The safety gear had been perfected, and, although no such thing as finality was possible, he did not think that much improvement could be expected in the future. The advantage of electric lifts was, as the Author had stated, that power was used in proportion to the load. With the hydraulic lift it was necessary to fill the cylinder whether the load was light or heavy; but with the electric lift the current was in proportion to the number of persons carried. To give an instance, the Otis Elevator Company had been asked two years ago to design a machine for a large establishment in London to carry a given load, possibly 1,000 lbs., to a height of 70 feet, at a certain speed. It was found that the current to drive the electric lift at 4½*d.* per unit would cost between £19 and £20 per annum; and that a hydraulic elevator under similar conditions, with a similar load and lift and doing similar work, would cost £47 per annum. The electric lift had then been decided upon, and the anticipations had been amply confirmed by results. The accounts for current for the first few months were at the rate of between £20 and £22 per annum, and at present, although the number of trips had increased from two hundred to three hundred per day, and although the loads had increased, the average cost of current was about £24 or £26 per annum. The Otis Company had made in past years a great many more hydraulic than electric elevators. They were compelled to place the best article before their employers, and if they were tied down to low cost of maintenance, they would advise electric instead of hydraulic lifts. As to the question of reliability, a hydraulic lift was simple, but an electric lift was equally simple, the switch-gear being the only part open to criticism on the score of complication. With regard to the question of initial cost of lifts, it was difficult to give exact figures, because every case had to be separately considered, as it depended upon different conditions. He might say that electric lifts for high buildings were as a rule between 10 per cent. and 15 per cent. more expensive in first cost than hydraulic lifts, depending on the height. The 10 per cent. or 15 per cent., whichever it might be, when capitalized, was saved over and over again in the difference in the cost of working. Taking an ordinary load of 800 lbs. or 900 lbs., twelve trips could be made with an electric machine against six with a hydraulic machine. Mr. Unwin.

Mr. W. H. Preece, C.B., Vice-President, said Mr. Walker, with considerable boldness, had called upon the electrical-plant manufac- Mr. Preece.

Mr. Preece. turers to support the facts which had been given in favour of electricity as applied to lifts and cranes. He was a considerable electrical user, and had early seen that electricity, if it possessed any merits, had the merit that it was particularly adapted for application to the very simple mechanical operation of lifting weights to a certain height. As soon as he had had the chance, he had applied electricity to working lifts, to which purpose he had considerable experience in the application of hydraulics. The great merit of electricity was, that it could be applied where it was wanted, that it could be used when, and only when, it was required; there was no waste in the meantime, and it could be stored quite as well as hydraulic power. He had, at the Post-Office at Leeds, three lifts worked by electricity. One was a short lift, only used for lifting parcel-baskets, bags, mails, etc. It made three hundred trips a day, and its height was only 12 feet 2 inches. The other two lifts had a run of 52 feet. He had made careful and accurate experiments upon those lifts, on the same system as that adopted by the Author. In the Table on p. 35 would be found the load, the travel, the time, the power, the energy, and the cost of working. Those engineers who loved the horse-power, and did not understand the Watt, would find both in that Table, so that both the old and the modern engineer could gratify their feelings in regard to the unit which each used and understood. In Leeds the cost of working each lift was almost exactly £7 per annum, and there were three lifts working there at a total cost for twelve months of £22 14*s.* 8*d.* He had also sent out to the Cape of Good Hope two lifts for use in the General Post Office there. They had been very carefully measured and tested, and their total efficiency worked out at about 40 per cent. In other words, the electric motors worked with an efficiency of over 80 per cent., and the gearing of the lifts themselves had rather a lower efficiency. At the General Post Office in London there were several hydraulic lifts, which were very largely used. Their average load amounted to six persons per trip, and the average number of trips was two hundred and twenty-eight loaded trips, the total number of trips being much more; 4,560 gallons of water per day were used, being received from the London Hydraulic Company. One was a ram lift, and another a suspended lift, similar to that suggested by Mr. Walker. The ram lift cost £123 10*s.* per annum, and the suspended lift £94 per annum. The height of the lifts was 84 feet in the General Post Office, as against 51 feet at Leeds; and the average load in the General Post Office was higher than the average load at the Post Office in Leeds. The

Mr. Preece.

TESTS OF THE ELECTRIC LIFTS AT THE POST OFFICE, LEEDS.

	Lift No. 1.[1]						Lift No. 2.[2]						Lift No. 3.[2]					
No. of Test . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
E.M.F. constant 105 volts. Direction	up	down	up	down	up	down	up	down	up	down	up	down	up	down	up	down	up	down
Load, lbs.	0	0	448	448	896	896	0	0	448	448	896	896	0	0	448	448	896	896
Travel, ft.	12	12	12	12	12	12	51	51	51	51	51	51	52	52	52	52	52	52
Time per trip, secs.	19	19	17	17	19	17	37	39	38	38	40	35	38	41	38	38	40	38
Maximum current, amps.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Average current . amps.	3	15	13	10	21	5	10	28	15	17	28	8	3	27	15	17	26	5
Duration of current . secs.	19	19	17	17	19	17	37	39	38	38	40	35	38	41	38	38	40	38
Energy per trip, watt-hours	1·66	8·31	6·44	4·95	11·63	2·47	10·7	31·8	16·61	18·6	32·6	8·1	3·3	32·2	16·61	18·6	30·3	5·5
Cost per single trip at 1½d. per unit . . .	·0025	·0125	·0096	·0074	·0174	·0037	·0160	·0477	·0249	·0279	·0489	·0121	·0049	·0483	·0249	·0279	·0454	·0082
Cost per double trip at 1½d. per unit . . .	0·01495		0·0170		0·0211		0·0637		0·0528		0·0610		0·0532		0·0528		0·0536	
Average current from meter reading, amps.	3	15	13	10	21	5	10	28	15	17	28	8	3	27	15	17	26	5
Average speed, feet per minute	37·9	37·9	42·3	42·3	37·9	42·3	82·7	78·4	80·5	80·5	76·5	87·4	82·1	76·1	82·1	82·1	78·0	82·1

[1] Platform, 5 feet 8 inches × 7 feet 6 inches, constructed to carry 15 cwt. Balance weight = cage plus 4 cwt.
[2] Cage, 2 feet 10 inches × 3 feet 6 inches, constructed to carry 8 cwt. Balance weight = cage plus 4 cwt.

Mr. Preece. mean cost per lift for equal loads and equal heights worked out, for the hydraulic lifts £35 a year, and for electric lifts £7 a year; so that, from actual experience, the cost of working an electric lift against a hydraulic lift was in the instance given as 1 to 5. The electric power was developed on the premises. With regard to speed, Mr. Ellington had suggested that the electric lift was slow. The average speed very nearly approached 2 feet per second in the electric lifts. A rate of 300 feet per minute was not comfortable travelling; 2 feet per second was fairly comfortable, and he believed the average was rather below 1 foot per second; so that with regard to speed he did not think any comparison could be drawn, since they were equal. In regard to staff, it was only the difference between a skilled mechanic and a skilled electrician; his experience was that a skilled electrician required less training than a skilled mechanician. With regard to storage, he would say that whatever could be done with a hydraulic accumulator could be done with an electric accumulator. He knew many places where nearly two-thirds of the work of the electric-lighting station was performed by energy stored in accumulators. Many people thought of electric accumulators of to-day as accumulators which existed 10 or 12 years ago, but he could assure them that the electric accumulator of the present day was as different from the electric accumulator of the past, as the water accumulator of to-day was compared with the rough machinery used in the last century. He thought the Table showed that electricity as a motive power applied to lifts and cranes, was not to be brushed aside with old-fashioned notions.

Mr. Ravenshaw. Mr. Ravenshaw, in reply, considered the efficiencies given in the Paper for the electric crane were low rather than high. He had known electrical cranes which had given higher efficiencies, but the case in point was a special one. It was a large crane, and power was lost in the gearing. The loss in the electrical part was 10 per cent. at full load, and in the gearing about 40 per cent. There was a very heavy chain barrel, and a large weight of chain down the vertical girder which had to be balanced by a heavy hook. In the crane mentioned there was a switch, Fig. 6, Plate 1, by which the motor could be started very gently. He had not advocated either the three motors or the single motor. He thought the three motors in many cases could be used with great advantage; but there was the disadvantage that it was possible to apply an inordinately large current, which responded very rapidly, and caused damage. The instruments were all carefully calibrated after the tests, and the results were the average of a great number

of readings. He had not advocated electrical over hydraulic lifts, because he was certain that hydraulic power would not entirely give place to electricity. A hydraulic lift was certainly very simple, especially when there was a single ram. Mr. Ellington complained that the lift he had ridden in in Berlin did not start immediately, that it lagged and hesitated. Possibly it was a lift made by a German firm, and of which he had recently seen the mechanism. It had an escapement gear, and passengers had to wait till the escapement ran half way down before the lift would start. He believed the escapement did not reach the bottom at all. With regard to jerking, he had himself gone up and down a hydraulic lift which had caused him great concern. It sometimes went very fast and sometimes very slow; sometimes it could not be stopped, then it was suddenly reversed, and there was a great jerk. He had spoken to the makers on the subject, and they said that it was the fault of the man who worked the lift. A new man was then employed, and the jerking did not now take place. This showed that care had to be taken in working hydraulic apparatus. He had ridden in many English electric lifts, and as a rule they worked very steadily. The rope could be pulled right down to the bottom, and it started smoothly. As to the small number of working parts; the electric lift gear, Figs. 1–3, Plate 1, showed only two working parts, namely, an armature and worm-wheel. In the lift gear shown there was a second guide-wheel, but many lifts had not that. In the jigger lift there were more than two working parts. As to being able to apply a large amount of power, that was done every day in the case of electric railways. He did not think there was any difficulty in that respect, with heavy fly-wheels and automatic expansion-gear, especially with the accumulators now being used. With regard to the cost of transmitting power by electricity, generating plant for electricity cost about 25 per cent. more than for hydraulics, the engines and boilers required being the same. Where overhead wires could be used, the cost of the electrical conductors was much less than that of hydraulic pipes; but where underground conductors were used, the cost was about the same. The increased cost of electric motors and gear was about 25 per cent. greater where a short travel was required; but for hauling-engines, where a rotary motion was necessary, he did not think there was much difference. He had experience of a great many plants on both systems, and had based his figures on practice. As to repairs, electricity had a great advantage over hydraulic power as it was not affected by frost. He had fitted hydraulic cranes with

Mr. Ravenshaw.

Mr. Ravenshaw. electric wires to heat the pipes and cylinders to prevent freezing, and had effected a saving of nearly £100 a year in repairs per crane in consequence. With properly constructed electric motors the repairs and maintenance did not exceed 5 per cent. per annum. As to cost of working, in a typical plant where the power was transmitted over an area of, say, 1 square mile, the losses were approximately as follows:—In dynamos 8 per cent., in cables 8 per cent., in motors 10 per cent. under varying loads, or a total loss of 24 per cent. The engines could be taken to deliver power to the dynamos at a cost of £8 per brake HP. per annum, so that the power would cost £10·5 per brake HP. per annum at the motor-shaft. Electric motors were remarkably well suited for travelling cranes, and could be arranged so simply that they could be very easily adapted to existing machines. This application was an extremely important one, and a large number of square shaft and rope-driven cranes had been adapted to work by electricity in the last few years.

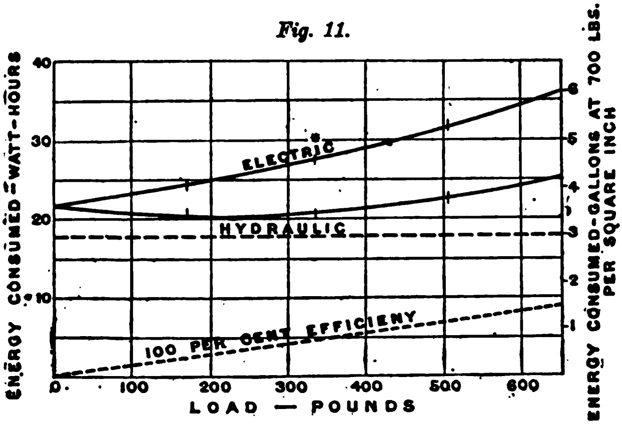
Correspondence.

Mr. Aspinall. Mr. John A. F. Aspinall remarked that in the erecting shop at Horwich good illustrations were afforded of the advantages of driving overhead cranes with electric motors instead of ropes. There were twenty 30-ton cranes in this shop, driven in pairs, with a single rope 1⅝ inch in diameter, 600 feet long, weighing 3½ cwt. and running at a speed of 3,880 feet per minute. Each of the ten ropes with their pulleys absorbed 15·5 HP. The energy required to lift a 46-ton engine with two cranes was only 16·4 HP. including internal friction. The ropes had been dispensed with and a single motor fitted to each crane with most advantageous results. Another application of electricity to lifting work was shown by an arrangement he had had introduced in the Victoria (Manchester) Station of the Lancashire and Yorkshire Railway for the transmission of parcels from point to point. The arrangement was unique and, he believed, the first of its kind. It had been running for 2 years and lifted baskets containing 8 cwt. of parcels, and, when high enough, ran with them at about 8 miles an hour. It covered about 100 miles a week, lifted about five hundred or six hundred baskets of parcels, and had consumed on the average 45 B.T. units of electricity in the same time. The current was taken from the electric-lighting circuit and passed from one rail through the machine, returning through to the second rail.

Mr. H. S. Cotton noticed that the Author advocated a gear with a quick pitch for the worm. With a worm of sufficiently flat pitch to make the gear self-holding there was at any rate a loss by friction of about 50 per cent. of the energy required to work the lift, but even in hand-power goods lifts self-holding gear was almost always employed, notwithstanding this loss on account of the gain in safety and simplicity. It appeared a retrograde step to permit in an electric lift the holding of the cage in position at the various floors to be dependent on a brake brought into action by an extraneous machine, viz., a spring or a falling weight. In a hydraulic lift, whether of the suspended or direct-acting type, the position of the cage was directly controlled by the admission or release of the water, and when the power was shut off, the cage was locked in position by the water in the working cylinder. In comparing the working of hydraulic and electric lifts the pressure of the water-power available was important. Many lifts were worked from the domestic supply mains, and these were sometimes miscalled hydraulic lifts, though the pressure available was seldom as much as $\frac{1}{20}$ of the ordinary hydraulic pressure of 700 lbs. per square inch. With low-pressure water the supply-pipes and lifting machinery were bulky and expensive, and, unless large reserve tanks were specially provided, the domestic supply was rarely sufficiently constant in pressure to give an efficient result. When water at a pressure of 700 lbs. per square inch was available, it was regularly adopted as the most suitable power for lifts and cranes; he was not aware of any instance of a lift formerly worked by hydraulic power at this pressure from the public mains having been replaced by an electrically-driven lift. The curves in *Fig. 11* indicated energy consumed in watt-hours, and the equivalent in gallons of water at a pressure of 700 lbs. per square inch. The lower inclined straight line showed the energy required to raise different loads to a height of 36 feet 6 inches, assuming an apparatus with an efficiency of 100 per cent. The horizontal straight line showed the energy, viz., 3 gallons, the equivalent of 18 watt-hours, consumed by a simple hydraulic suspended lift in raising the load to the full height at a speed of, say, 180 feet per minute. The flat curved line next above the horizontal line was the upper curve given for the electric lift in *Fig. 4* of the Paper, and showed the energy consumed at different loads when the cage was taken up and down again with the same load; in the actual work of a lift such circumstances occurred very rarely. The upper curve showed the energy expended by the electric lift when different loads were taken up and the cage Mr. Cotton.

Mr. Cotton. was brought down empty. This curve with no load showed 20 per cent. more energy consumed than by the simple hydraulic lift at full load; and when the electric lift was working at its highest efficiency of 25 per cent., as shown on the diagram, the consumption of energy was double that of the hydraulic lift. The results for the consumption of energy by an electric lift given by the Author were apparently for working the cage up and down without stopping at any intermediate floors. This did not prevail in practice, and the cage would sometimes be stopped at each floor, and on the average at certainly more than one floor for each trip. With a hydraulic lift, the consumption of power was not increased, however frequently the cage was stopped, the energy being always consumed in proportion to the height travelled. The results for an electric lift given by the Author in columns 5 and 15, Appendix I,

Fig. 11.

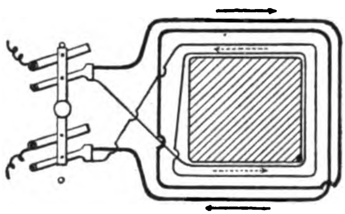


showed the energy consumed to be relatively considerably higher with a shorter travel, viz., 8·3 watt-hours, with a travel of 24 feet 9 inches, and 11·12 watt-hours, with a travel of 36 feet 6 inches. Assuming, apart from the power consumed in starting and stopping the cage, the energy used to be proportional to the height travelled, these results showed that, when the cage and load were balanced, it required 2·2 watt-hours of energy to start and stop the cage once on the up journey. The increased consumption, amounting to 8 per cent., due to one additional stop on the journey with a load of 336 lbs., was marked at *. At higher loads, with the cage stopping at the intermediate floors, the consumption of energy by the electric lift would presumably be largely increased.

Mr. Scott. Mr. E. Kilburn Scott remarked that in modern practice the objection to the end-thrust in single worm-gear, representing as

it did about 20 per cent. of a total of 30 per cent. lost in friction, was overcome by employing duplex worms on the motor shaft, one right-handed and the other left-handed. The two worm-wheel shafts were meshed together, and thus each worm only took half the load, and consequently its life was much prolonged. Again, besides there being a total absence of end-thrust, experience would appear to show that the actual friction of the worms themselves was less than with a single worm and worm-wheel. An efficient ball- or roller-thrust bearing was expensive; and it should also be remembered that it was detrimental to use any but the best lubricants. All the earlier lift-motors were reversed by reversing the direction of current through the armature, but the Otis and other types of lift were now generally fitted with field control—the current in the field-magnet coils being reversed at each journey up or down. For eliminating permanent magnetism, and at the same time reducing sparking, "reverse coils," consisting of several windings placed alongside the field coils, *Fig. 12*, were used with the Eickemeyer motors on the Otis lifts, and were thrown into circuit each time the field circuit was cut off. On throwing over the switch shown in the *Fig.*, the current due to the field-magnets losing their magnetism had a path open to it in the opposite direction round the field magnet (as shown by the arrows), and the arrangement was therefore very effective in reducing residual magnetism, and so facilitating the working of "field-controlled" motors. He thought that in the automatic throttling rheostat, as used in electric lifts, there was something wanting—at any rate for the higher speed passenger service of, say, 250 feet per minute, especially when considered from the point of view of its useful working life. When it was remembered that a high-speed passenger-lift must gradually start and travel, and then gradually stop again in moving from one storey to the next in, say, 4 seconds to 5 seconds, it would be seen that the automatic action had to be very quick. On this account also the *vis-viva* of the armature and gear must be as low as possible, and it was probably this fact more than any other which had proved the small squat Eickemeyer motor to be so eminently suitable for the work. Mr. Scott.

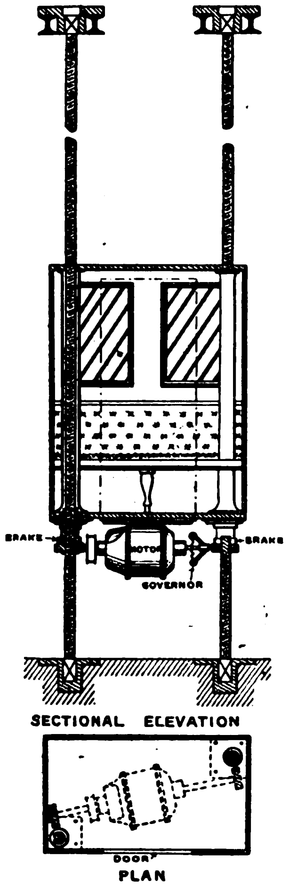
Fig. 12.



Electricity had an advantage over hydraulic power in that

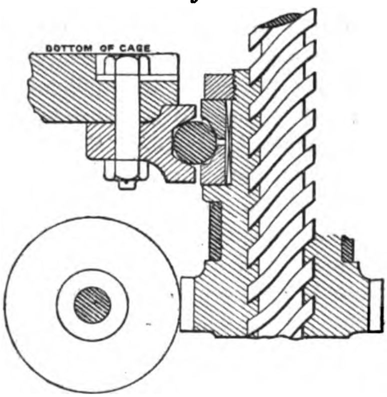
Mr. Scott. it was very easy to conduct the electric power into the car; but so far as he was aware, this had only been taken advantage of for the purpose of putting switches and regulating devices on the car; the pilot motor regulation which Mr. Sprague used on his screw lifts being a case in point. In view of these facts, he had designed an arrangement in which full advantage was taken of the flexibility of the electric system, whilst at the same time realizing high-speed service, exact stopping at the floors, and maximum safety. The arrangement consisted of two steel spindles screwed along their whole length with a double thread of about 3-inch pitch; they were firmly held from revolving at both ends of the car-race, and passed through the corners of the cage as shown in *Figs. 13.* An electric motor was attached to the lower side of the car, which was supplied with current either by means of hanging cables or by slippers pressing against copper strips fixed to the side of the car-race. The motor drove two pairs of skew-wheels, arranged right-hand and left-hand, thus effectively getting rid of end-thrust. The driven wheels, *Fig. 14*, to a larger scale, formed the nuts to the screws, being split so that they could be readily replaced. The friction between the nut and the screw might be reduced by having steel balls between their respective threads, as in the Sprague lift, but owing to the very quick pitch of the thread he did not think this was required, and, as would be seen, a conical roller or ball-bearing was interposed between the cage and the nut. In descending with a heavy load, the motor might be used as a very efficient brake by being short-circuited on itself or being temporarily turned into a generator, in the same way as on some of the electrically worked mountain-railways in Switzerland; and thus in a building where there were several lifts, they might be made to help one another.

Figs. 13.



Mr. Scott. There were some disadvantages in the arrangement, but on the other hand there was the great advantage that the car-attendant had the power directly at his feet, and could at any time see exactly how the motor, switches, &c., were working. Great safety and exact stoppage at floors were also secured, and the arrangement was self-contained, as no starting-rope with its sheaves (or its more complicated equivalent, the pilot-motor) was required. In order that the extra weight carried by the cage might be as small as possible, he had designed a motor for the work which had its magnetic circuit made entirely of laminated iron; the frame and the two bearings being made of an aluminium alloy, which, whilst being almost as strong as cast-iron, was only about one-third its weight. The same method could be worked out with a rack at the side of the car-race, or the motor might be fitted with a winding drum, and haul itself up and down. These did not give the safety of two screws, but in any case there seemed to be no valid reason why the beautiful flexibility of electricity should not be taken full advantage of by placing the motor on the car itself.

Fig. 14.



Mr. Tapscott. Mr. R. Lethbridge Tapscott observed that electrical transmission rendered available a single source of energy for the various requirements of extensive works, which formerly involved the use of gas for lighting, steam to drive the shafting for working the numerous machines, and to drive the pumps for obtaining the pressure necessary to work hydraulic presses. The question now arose whether the hydraulic pressure could be usefully replaced by the electric current, or by an electric motor used to work the accumulator. The working of the travelling crane had now been perfected; but there remained for improvement the haulage of the trucks and trolleys through the works, without overhead wires. When these could be replaced by some simple arrangement, it would be possible to convey the power by easily disposed cables, free from the objection to running shafting, and possibly with greater economy of the initial steam-engine power. He assumed that the Author was describing the lifting of the heaviest weight

Mr. Tapscott. yet attempted by electrical power and with the fewest electrical machines; it would appear, however, that by having only one motor, three sets of gearing and two minor electrical appliances were necessary. He therefore asked whether, in addition to the dynamo supplying the power, three independent motors, one for lifting the weight, another for travelling the crane, and the third for traversing the weight, would not be more economical and render unnecessary all the gearing, besides enabling the coupling of the hoisting-drum direct to the motor. The rotation of the drum would then be the same as the rotation of its motor, and the power from the motor receiving the current from the supply-station would be treated so as to rotate the motor carrying the hoisting-drum slowly; and by the introduction of suitable magnets the current would then be used as a brake. The Author, however, appeared to have satisfied himself by experiment that the gearing was preferable to the multiplication of electrical appliances, while acknowledging that the switching on and off of a current was such a simple process; besides, there was the case of locking with the current by the use of magnets, which appeared so simple that he was disposed to think that the gearing might eventually be dispensed with in such machines.

Mr. Thorpe. Mr. R. H. Thorpe said that motors connected with winding machinery had to start their loads from rest, and accelerate them smoothly and as quickly as possible without using large power from the supply circuit. In order to fulfil these conditions a shunt motor with a few series turns was not enough, since the starting and accelerating current, under such conditions, would be nearly double the running current for maximum load. To fulfil the conditions without drawing heavily on the mains required a motor giving a starting torque at least double the running torque, such a requirement could not well be filled with such a small motor as the Author proposed, even if the motor only occasionally did maximum work. It was well known that properly constructed worm-gear gave a very good efficiency, where the pitch was made quick enough, as it naturally would be with high-speed elevators, running at speeds of over 200 feet per minute. The arrangement of rope transmission stated to be used by Messrs. Easton and Anderson, similar to that used by cable tramways, was not as well adapted to lifts as a fixed rope on the drum, since the automatic devices for stopping the car at the top and bottom must be more complicated, and therefore, for every-day use, were not as reliable. No mention was made in the Paper of a very interesting system of controlling lifts which gave ideal results

in respect to starting and stopping. In this system the motor Mr. Thorpe. received its power from a special generator. The armatures of the generator and motor were connected, the motor field was constantly excited from an independent source, the generator field being controlled by a switch in the car. The generator armature was kept revolving at a constant speed, so that the power supplied from it was under control of a car-switch worked by the attendant. The whole operation was therefore electrical, and no mechanical brake was used, and, consequently, all jars were avoided. Even at the highest speeds the car started and stopped without vibration. The drawback was the extra generator, and consequent cost and additional space required. The starting device designed by the Author required, as explained by him, only so much resistance as was needed to allow the maximum current to start the motor with the maximum load. This was permissible for small duties and motors designed with large starting torque. For heavy-duty lifts such an arrangement was objectionable, since it was not permissible on supply circuits of moderate size to use the maximum current for maximum loads every time a motor was started; yet where a centrifugal governor reduced the resistance, it became necessary to allow for every load the maximum current, since no resistance could be cut out unless the motor had first started its load. Where the Author employed a solenoid with a shunt winding connected with the armature terminals, unless this magnet was very powerful it might refuse to work when the contacts became rough; and, on the other hand, his method of working was uncertain, since it was not impossible that the brush, after having cut out all resistance, would not drop back to the starting position when the motor stopped, the operation depending upon gravity alone. Thus when the car was started again, the limiting resistance was not in the circuit, and in closing the switch damage might be done to the armature. The magnet brake advocated by the Author was not the best for lifts, it was not as reliable as a well-constructed mechanical brake, since it was possible that the wire on the brake magnet might become earthed, and thus prevent the magnet from dropping. For lifts of high efficiency, doing sufficient duty to allow the car to keep on running, or even to accelerate its speed if the supply circuit should be interrupted, the safest brake was a combination of a mechanical and a safety electric. The buzzer described by the Author was used by Messrs. Otis Brothers in 1889, and had since been abandoned, as was the visual indicator which followed it. The tests made and tabulated, of the Otis lift, were for the

Mr. Thorpe. smallest-sized passenger machines, and necessarily, therefore, the efficiency was comparatively low. Large passenger machines of that type showed an efficiency between actual load lifted and power consumed by motor of 70 per cent. The Paper could have reference only to passenger lifts for very light duty, and presumably indicated the state of electric-lift practice in England.

Mr. Webb. Mr. F. W. Webb remarked that the travelling cranes in the Crewe Works, some fifty-three in number, had been constructed for rope or cord driving, and, generally speaking, the results had been satisfactory, although loss in power was inherent to the system. He had early felt convinced that electric power might be applied with many advantages; it was not, however, until the latter end of 1889 that a somewhat serious accident occurred to a workman due to the breaking of a cord running at a speed of about 5,000 feet per minute, which induced him to substitute experimentally electric power for the cord in one of the cranes. The new system had been put to work in the early part of 1890 with such encouraging results that he had since applied it to nine others, and he anticipated that in the course of a few years all the cranes at Crewe would be electrically driven. Of the ten cranes altered two had each a lifting capacity of 4 tons, three of 10 tons, one of 15 tons, and four of 30 tons. The motors, switches, and other electric apparatus, which were constructed at Crewe, were all of one type, but varied in dimensions to suit the varying powers required. The armatures were of the Gramme type with Paccinotti teeth. The field-magnets were of the Manchester type and were cast in mild steel specially made for the purpose at Crewe. An independent motor was provided for each of the three movements of the crane. In the case of the lifting and long traversing movements the motors were of the same size, but for the cross traversing movement a smaller motor was provided. The magnets were energized three in series from a circuit which was never broken, the current in this circuit being about 1 ampere and the pressure 120 volts. The movements of the motors, which were reversible, were controlled by switches actuated by three short levers placed immediately in front of the crane attendant. In their normal position these levers stood upright, and they were pushed from him or pulled towards him in accordance with the direction he wished the movement to be made; and in each case the current on the first movement of the switch passed through a variable resistance formed from the scrap charcoal-iron left after forming the armature plates. This resistance was wholly cut out when the lever was pulled over. The switch contacts

were of carbon, the short ends of arc-lamp carbons being used for the purpose, and the same carbon was used for the motor brushes, which had a fixed position in relation to the commutator. All motors were constructed to run at a maximum speed of 1,500 revolutions per minute, a worm and worm-wheel transmitting the movement to the crab gearing. In the case of the 30-ton cranes used in the erecting shops for lifting locomotives, the load was lifted at a speed of 2 feet 6 inches per minute at an expenditure of 70 amperes at 120 volts. The long travelling was performed at a speed of 100 feet per minute with an expenditure of 60 amperes at 120 volts, and the cross traverse at a speed of 50 feet per minute with an expenditure of 30 amperes at 120 volts. In the case of light weights the speed of lifting was 10 feet per minute. In the case of the 15-ton crane, which had been provided in connection with a boiler-riveting plant, the crane was 50 feet above the floor-level, and all its movements were controlled by switches on the ground, a magnetic brake being provided on the armature shaft to arrest the motion as soon as a rivet-hole had been brought into place for the closing of the rivet. The cost of repairs had so far been very small; no renewal of commutators had been necessary, but they had to be lightly skimmed up in the lathe about once in 12 months. The carbon switches and brushes had to be renewed once in 6 months, and as this applied to cranes which were very heavily worked the result was considered satisfactory. He took the opportunity of acknowledging the services of Mr. A. M. Thompson, M. Inst. C.E., his chief assistant in charge of the electrical and signalling departments, under whose supervision the work referred to had been carried out. Mr. Webb.

Mr. Ravenshaw, in reply to the Correspondence, thought the remarks of Mr. Aspinall and Mr. Webb bore out his experience that it was comparatively easy to apply electricity to an existing travelling crane. Electric transmission appeared to be specially suitable for this work, the energy being transmitted through fixed conductors, instead of by ropes or square shafts running at a high speed. He considered the use of a slow-pitched worm, the only advantage of which was the holding power due to its low efficiency, entirely wrong, and he had experienced no difficulty with the use of magnetic brakes. He was afraid the arrangement of vertical screws suggested by Mr. Scott would be very expensive and have a low efficiency. There was no difficulty in winding an ordinary motor of good design to give a good starting torque with a small current, without further complication in the switching arrangements. He preferred magnetic to mechanical brakes, and Mr. Ravenshaw.

Mr. Ravenshaw. when they were well designed and were controlled by a double-pole switch, there was no danger of their refusing to act. He was aware of the Leonard system, in which a motor generator was used, but he had not described it, as he did not know of its being in general use.

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6 April, 1897.

JOHN WOLFE BARRY, C.B., F.R.S., President, in the Chair.

It was announced that the several Associate Members hereunder mentioned had been transferred to the class of

Members.

John Beckett Baker.
Joseph Phillips Bedson.
George Dundas Churchward.
George Elmsley Coke.
James Fraser.
William Hayden Gates.
Nathaniel Grew.
William Silver Hall.
Samuel Hanna.
George Francis Horbury.
Francis William MacLean.
Sir Charles Herbert Theophilus Metcalfe, Bart.
Thomas Harold Rawson.

And that the following Candidates had been admitted as

Students.

Arthur Marshall Adamson.
John Edward Bostock.
Alfred Douglas Creer.
Hugh Geoffrey Elwes.
Walter Eraut.
Thomas Christison Fraser.
Alexander Grant.
Otto Max Constantin Heyl.
Harry Jackson.
Harry Oscar Jones.
Anthony Poignand Lambert.
Alfred Lines.
Malcolm Hunter Logan.
John Allan Cameron McCalman.
Laurence Lestock Mercer.
Leonard Meyrick Meyrick-Jones.
John William Richmond.
Percy Edward Shepherd.
Arthur Robinson Shutes.
Clifton Maclean Skinner.
Charles Frederick Smith.
Kenneth Basil Woodd Smith.
Charles Herbert Snellgrove.
Samuel Stansfield, B.Sc. (*Victoria.*)
Philip Beagley le Despencer Tree.
Harold Williams.

The Candidates balloted for and duly elected were: as

Members.

Francis Edward Dyke Acland, *Capt.* R.A. *ret.*
John Harvard Biles.
Allen Mason Brand.
Albert John Durston, C.B., R.N.
John Byron Gisborne.
Nathaniel Robert Griffith, A.R.S.M.
William Porritt Ingham.
Henry Morley.
Fred Stark Pearson.
Jorge Black Scorrar.

Associate Members.

Donald Stewart Arbuthnott.
Samuel George Armstrong.
William Henry Bickerton, Jun., B.Sc. (*Victoria.*)
Robert Smith Black.
George Robertson Blake.
Benjamin Branfill.
Arthur George Bristow.
Harrison Francis Bulman.
Herbert Carpmael.
George Grant Chapman.
Oliver James Collis.
Francis Edward Cooper.
Douglas Brenton Cox.
Luiz Gonçalves da Cunha.
John Hugh Davies.
Clement Frederick Davis, B.A. (*Cantab.*), Stud. Inst. C.E.
Frederic John Dixon.
William Havilland Druce.
Ernest Hubert Flower, Stud. Inst. C.E.
Alexander Gibb, Stud. Inst. C.E.
William Gore, Stud. Inst. C.E.
Frank James Gray.
Frederick Henry Grimshaw.
George Henry Hamby.
George Thomas Harrap.
Percy Hawkins.
Kenneth Phipson Hawksley.
John Angus Hay.
Frederic Walter Hodson.
Arnold Hackney Hollingsworth, Stud. Inst. C.E.
The Hon. Henry Worsley Holmes à Court, Stud. Inst. C.E.
Richard Hosken.
Cecil Gascoyne Howsin.
Alfred Hudson.
Walter James Hunter.
John Henry Jevons.
John Kirkwood.
Richard Charles Long.
James Meldrum.
John Rumney Nicholson.
Frederick Albert Nixon.
William Norris.
Alfred Patch.
Walter Patteson.
Edmond William Payne.
William Llewellyn Preece.
William Prest.
James Henry Price, Stud. Inst. C.E.
George Henry Raddin, B.E. (*Royal.*)
John William Melling Richardson.
John Robert Rodgers.
Henry John Rudgard.
William Salmond.
William Barboure Shaw.
Harry William Smith.
James Noel Sparks, B.A. (*Cantab.*)
William Stratford Strettle, B.C.E. (*Melbourne.*)
Charles David Szlumper.
Alfred John Terry, Stud. Inst. C.E.
Ernest Frederic Crosbie Trench, B.E. (*Dublin.*)
Pierce Joseph Tucker, Stud. Inst. C.E.
Harry Smith Wainwright.
Albert Harry Walker.
Archibald Edward Walker.
Thomas Harkness Watt, Stud. Inst. C.E.
Henry Alfred Willey.
Francis Stuart Williamson.
Alexander Cowan Wilson.
Henry Wootton.

The discussion upon the Paper on "Electric Lifts and Cranes," by Mr. Henry W. Ravenshaw, was continued and concluded.

13 April, 1897.

WILLIAM HENRY PREECE, C.B., F.R.S., Vice-President, in the Chair.

It was announced that Henry Richard Clarke Pauling, Associate Member, had been transferred to the class of Members.

(*Paper No. 3021.*)

"The Blackwall Tunnel."

By David Hay, M. Inst. C.E., and Maurice Fitzmaurice, B.E., M. Inst. C.E.

The necessity of communication between the north and south banks of the Thames below London Bridge other than by ferry was pressing even in the beginning of the present century, and it has become accentuated as the manufacturing districts have extended eastward along the river. A comparison of the crossings above and below London Bridge with the respective populations east and west of the bridge, will show that the east of London is still badly provided for in this respect.

Historical.

A tunnel to connect Tilbury with Gravesend was commenced in 1798, but the work did not proceed beyond sinking a shaft at one side of the river, as the difficulty experienced with it exhausted the capital of the undertaking.

In 1805 a tunnel between Limehouse and Rotherhithe was commenced by Vazie; a shaft was sunk and a heading driven under the river for a distance of more than 1,000 feet, but the river then broke in and the work was abandoned.

In 1825 Brunel commenced the tunnel between Wapping and Rotherhithe, which, as is well known, is built of brickwork, and consists of two arched passages. The outside width of the brickwork is 37 feet 6 inches, and the height is 22 feet 3 inches. The shield was made in twelve separate sections, each capable of being driven forward separately, by screws abutting against the completed brickwork; and the ground between the shield and brickwork, as the former advanced, was supported by plates fixed to the shield and sliding on the back of the completed

work.[1] The river broke into the tunnel several times during construction, and, after a serious irruption on the 28th August, 1828, the work was stopped until January, 1835. The first shield was then replaced by a new and stronger one, though still on the same principle, and the work was finally completed in 1842. The length of the tunnel was about 1,200 feet, and work was in active progress for about ten years, so that the average progress was only about 120 feet per annum. The cost, including shafts, was about £1,300 per lineal yard. This tunnel, originally intended for road traffic, is now used by the East London Railway. It is interesting to note that here, as at Blackwall, much of the excavation was through clay which had been tipped from barges on to the river bed, and which came down as the sand and ballast beneath ran into the shield.

The only other tunnel constructed under the Thames below London Bridge was the Tower Subway, built in 1869 by Mr. Peter Barlow, F.R.S., Past-President, and the late Mr. J. H. Greathead, M. Inst. C.E. This tunnel was kept at a low level so as to be in London clay throughout, and consequently no trouble was experienced from water. A shield driven forward by screws was used, and a cast-iron lining was adopted for the first time.

In 1876 Mr. Greathead started another subway between North and South Woolwich, but the work was never completed.

Schemes for tunnels at different points below London Bridge have been brought forward from time to time, the most important of which were those proposed close to the site of the present Tower Bridge, at Nightingale Lane, and at Shadwell; and subways for foot-passengers at Limehouse and Greenwich. On account of the docks on both sides of the river, there are few places east of London Bridge where a tunnel for vehicular traffic could be made to tap the main lines of traffic, and at the same time allow good approaches.

About the year 1875 it became generally recognized that the construction of more river crossings below London Bridge could not be further delayed, and the matter was taken up by the Metropolitan Board of Works, who brought forward several schemes both for bridges and tunnels; but it was not until 1887 that the Blackwall Tunnel Act was obtained. The design, as proposed by Sir Joseph Bazalgette, consisted of three tunnels, two for vehicular traffic, and one for foot-passengers; and it was determined to construct the latter in the first instance. The internal

[1] By the courtesy of Messrs. Maudslay, Sons and Field a model of this shield was exhibited.

diameter was to be 15 feet, and the tunnel was to be made of cast iron, and to be lined with brickwork. A cross-section of the tunnel, and of the shield which Sir Joseph Bazalgette proposed to use in its construction, are shown in Fig. 9, Plate 2, and Fig. 12, Plate 3. Tenders for this work were invited, and it was decided to let it to Messrs. S. Pearson and Son; but owing to the Metropolitan Board of Works being replaced by the London County Council, and the latter body considering that a larger tunnel ought to be made at once, the contract was never carried out. It was then three years before the final decision was made, and at the end of 1891 the contract for the present tunnel designed by Mr. Alex. R. Binnie, M. Inst. C.E., Chief Engineer to the Council, was obtained by Messrs. S. Pearson and Son, the amount of their tender being £871,000. The total length of the tunnel is 6,200 feet, 1,220 feet of which are below the river. The lengths adopted for each type of construction are shown in Fig. 1, Plate 2, that of the cast-iron lined portion being 3,112 feet. The gradients on each side rising to existing roads involved interference to a large extent with the sewers, which had to be diverted and reconstructed. A large amount of this work was carried out, but, with the exception of the reconstruction of the Isle of Dogs low-level sewer, an egg-shaped sewer 10 feet by 6 feet 8 inches, where difficulty was experienced with water, and where the flow of sewage could not be interfered with while connecting up the old and the new work, it was of ordinary character. This sewer was constructed partly in tunnel and partly in deep open-cut, for a long length of which a 6-foot barrel was carried on the arch of the larger sewer. Several smaller brick sewers were constructed, as well as a number of pipe-sewers of diameters of 2 feet and less. The total cost of the work of this kind was about £40,000.

Open Approaches.

The open approaches on each side of the river extend from the ends of the cut-and-cover work to the points where the roadway attains the existing road-levels. The construction adopted consists of concrete and brick retaining walls with a concrete invert between them. On the Middlesex side the excavation was almost entirely in clay or made ground, and there was little difficulty with water. The excavation was taken out to the full width before any concrete or brickwork was inserted, and, except at the deep end, very little timbering was necessary. On the Kent side the work at the deep end was almost wholly in water-laden ballast.

The side walls were first built in timbered trenches, and the dumpling was afterwards excavated and the invert inserted. By this mode of construction there is no danger of a longitudinal fracture between the walls and the invert, due to unequal settlement, and lighter timbering is required for the narrow trenches than for a trench embracing the whole of the structure. Skew-backs were formed at the bottom of the walls to receive the invert, and as this temporarily reduced the base, timber struts were placed between the two walls at about the road-level when the dumpling was excavated to that point, until the invert was constructed. A cross-section at the deep end of the open approach is shown in Fig. 2, Plate 2, the section being the same on both sides of the river. The brickwork has a white glazed face and is bonded into the concrete, being alternately 9 inches and 18 inches thick, in equal lengths of 3 feet. As water-tightness was absolutely necessary, the walls were coated with $1\frac{1}{2}$ inch of asphalt, which was carried down the back to within 3 feet of the bottom and thence across through the invert. This gave a continuous water-tight layer completely surrounding the work, which has proved satisfactory. At one or two places, owing probably to expansion and contraction due to changes of temperature, cracks have appeared, but the amount of leakage is almost inappreciable and is carried away in small pipes connected to the road gully-pipes.

Cut-and-Cover Portion.

The original intention was to adopt this mode of construction for lengths of 436 feet and 335 feet on the Middlesex and Kent sides respectively, in accordance with the cross-sections shown in Fig. 3, Plate 2. In carrying out the work, however, on the Kent side the ground was found to be better, and less difficulty was encountered from water than was anticipated; so it was decided, after inquiry as to the relative cost, etc., to extend the trench-work by 582 feet. This brought it to No. 4 shaft, the point from which it was arranged to drive the shield northwards. The first section consisted of four layers of brickwork, built in concentric rings, surrounded by a band of asphalt $1\frac{1}{2}$ inch thick, and by 6 to 1 cement concrete which was backed up by clay puddle. The puddle backing, however, was found unsatisfactory, notwithstanding the fact that it was rammed as stiff and solid as possible, as the side walls began to spread slightly when the filling was placed on the arch. To prevent further movement, piles were driven through the filling into the puddle; the use of which was

thereafter discontinued and the section shown in Fig. 4, Plate 2, substituted. The concrete was built tight to the sides of the trench, and the asphalt was mainly relied upon for water-tightness. The arch on the Middlesex side was also built to this section. In the deeper part of the cut-and-cover portion substituted for the iron-lined tunnel, on the Kent side, an extra ring of brickwork was added as shown in Fig. 5, Plate 2.

On the south side a sump 18 feet square was sunk outside the trench through the ballast and about 17 feet into the London clay. Pumping plant, consisting of two pairs of 24-inch, and one pair of 18-inch rocker pumps, of 4 feet and 3 feet stroke respectively, was provided to deal with the water. In the portion of the work where fall could be obtained to the sump, two sub-pipes, 18 inches in diameter, with rubble drain connections, were laid below the foundations to conduct the water to the pumps, and in the deeper part of the trench this was done by carrying the pipes on a garland or benching near the top of clay. The maximum quantity pumped amounted to about 150,000 gallons per hour, but after the pumps had been at work for some time, and the water-level in the ballast lowered, this quantity was considerably reduced. The resistance to the flow through the ballast towards the sump gave a gradient of about 1 in 36 to the top of the water. Only a small quantity of water was met with on the Middlesex side. The trench varied between 37 feet and 65 feet in depth, and between 37 feet and 42 feet in width at the top. Although it was very heavily timbered, and every precaution was taken to secure the timbering as the trench was sunk, a length of 140 feet collapsed during the night of the 24th November, 1893. Upon examination, however, this appeared to have been due to the washing out of ballast from behind the timbering through the bursting of a water-main.

SHAFTS.

There are four shafts in the line of the tunnel; Nos. 1 and 2 situated on the north side, and Nos. 3 and 4 on the south side of the river. Their positions, Fig. 1, were determined by the horizontal or vertical changes of direction of the tunnel, which was driven straight from shaft to shaft, the difficulty of driving the shield on a curve and the trouble and expense of special castings being thereby avoided.

Caissons.—The caissons, Figs. 6, are 48 feet in internal, and 58 feet in external diameter, and are formed of two skins, partly of steel and partly of iron. The plates, generally 4 feet in depth,

vary in thickness between $\frac{3}{4}$ inch at the bottom and $\frac{5}{16}$ inch at the top; they are stiffened by belts of angle-bars, carried round inside at every lap-joint, and are braced together by horizontal and diagonal angle-bars. The lower portion is constructed of steel to 8 feet 6 inches above the cutting-edge, which is formed by bending the inner skin outwards to meet the outer skin, and is stiffened by a band 1 inch thick and 2 feet deep, running round the outside, and by vertical plate diaphragms between the skins. The inner surface of the shaft is vertical, the plates being set at such an angle as to bring the upper edge of each into line with that of the plate below; the outer surface has a batter of about 1 in 100 due to the lap of the plates, which are arranged telescopically. The space between the skins, 5 feet near the cutting-edge and reduced by the outside batter to about 4 feet at the top, is filled with 6 to 1 Portland-cement concrete. There is an internal lining of brickwork with a glazed face, the finished diameter of which is 45 feet 8 inches. The floors of shafts are formed of 6 to 1 concrete 11 feet thick, near the bottom of which is placed a water-tight skin of wrought-iron, covering the floor and attached to inside of caisson by studs. Provision was made for attaching brackets or stools above the cutting-edge, so that the sinking could be controlled by timber packings beneath them.

Tunnel Openings.—Two openings are formed in each shaft, 29 feet $4\frac{1}{2}$ inches in diameter, on the centre line of the tunnel, and the caisson is strengthened round them by vertical and radial diaphragms. These openings were closed during the sinking by iron shutters bolted together so as to be readily removable in sections capable of being passed through the advancing shield. The shutters were carried on vertical and horizontal girders bolted to the caisson, as shown in Figs. 6. The joints were made with wooden packing and caulking between the shutters, and by cement between them and the tunnel openings.

Air-tight Floors.—Arrangements were made for attaching air-tight floors to the inner skin of caissons, above the level of the tunnel openings, for use either in sinking the shafts or constructing the water-tight floors should compressed air be found necessary, and when it was required to drive the tunnel through. The floor consisted of $\frac{5}{8}$-inch buckled plates resting on girders 18 inches deep; above these 4-foot girders were placed at right-angles, the whole being surmounted by two girders 12 feet deep. The ends of the girders and the buckled plates were attached to the inner skin of caisson, which, in the case of the 12-foot girders, was strengthened by a $\frac{1}{2}$-inch doubling-plate to take up the shear.

Stiff iron diaphragms or bulkheads were also built between the skins in the line of the two main girders. When the air-pressure exceeded 20 lbs. per square inch above atmospheric pressure, the upward thrust on the floor was relieved by 10 feet or 14 feet of water-ballast.

Method of Sinking.—The shafts on the south side of river were sunk by pumping down the water and removing the excavation from the inside in the ordinary way. The weight of caisson and concrete filling was generally sufficient to overcome the skin friction, until about 20 feet from the bottom, when more weight had to be temporarily added. The sinking of No. 4 shaft was accomplished without difficulty, the ground being good and almost cleared of water by the pumps for the cut-and-cover portion and the open approach about 200 yards distant; and, as very little water was found below the London clay, it was possible to construct the water-tight floor in the open. Considerable trouble was, however, experienced in dealing with No. 3 at the river bank. The ground for about 25 feet of the lower part of the shaft is composed of fine sand, and numerous "blows" were caused by the head of water in the ballast above (charged afresh by every tide), washing in large quantities of gravel and sand. The ground was of such a heavy clinging nature that the caisson was often stationary for several days, although the cutting-edge was free and the structure was heavily loaded; and it was not until a blow occurred, the movement of the ballast decreasing the skin friction, that further downward progress could be made. The caisson was at one time 14½ inches out of level, and various expedients were tried to induce blows on the high side in order to correct it. The best results were obtained by striking heavily on the inside of the shaft with a baulk of timber swung horizontally from a girder above. Considerable subsidence of the surface was caused by the sand and gravel entering the shaft; the wharf wall completely disappeared, leaving the river free to surround the caisson at every tide and to find its way through the numerous cracks in the London clay to the heading of the advancing tunnel. Some damage was also caused to the buildings of Messrs. Forbes, Abbott, and Lennard, 40 yards distant.

As all the weight had been placed on the skins for which room could be found, the girders of the air-tight floor were fixed and loaded; better progress was then made, and when the top water was cut off no difficulty was encountered in dealing with the springs in the sand below the London clay; the floor was therefore constructed, as in the case of No. 4, without the aid of

compressed air. In both cases the suction-pipes of the pumps were carried through the iron water-tight floor near the bottom of the concrete, and, after ascertaining that no sand was being drawn out with the water, pumping was continued until the concrete was thoroughly set, when the valves, which had been provided in the suction-pipes near the top of concrete, were closed. The friction on the outside skin for the last 20 feet in the case of No. 3 amounted to about 5·6 cwt. per square foot, the cutting-edge being entirely free. Little or no reduction of friction resulted from the outside batter in this case, as there is little doubt that the ground closed in almost instantaneously as the caisson descended. As it is sunk upon private property this shaft is covered by a dome, the inner skin of the caisson being set back about 34 feet below the surface to form a springer. A chimney 70 feet high is built on the centre of the dome for ventilation, and to prevent fumes from the tar distillery above from entering the tunnel.

On the north side of river No. 2 shaft was sunk, behind a new river wall, Fig. 1, which had been built to reclaim part of the foreshore. From four borings taken round the site it was ascertained that the whole of the ground to be penetrated consisted of ballast; and to avoid the difficulty and delay experienced on the south side, it was decided to employ a grab for the excavation, allowing the water to remain inside. The grab was worked by a 10-ton crane supported on girders inside the shaft; and, as the material was removed, the caisson was forced down by weighting it heavily, in addition to the concrete, with tunnel castings distributed round the top and on special brackets attached to the inner skin. The total weight of the caisson and sinking-load amounted to nearly 4,000 tons, the skin friction being therefore about 4½ cwt. per square foot of outside surface. Trouble was found at first in working the grab on account of the twisting of the long wire ropes; flat ropes were therefore substituted, and no further difficulty arose, the rate of sinking averaging 1 foot in twenty-four hours.

As it was not practicable to construct the floor without the aid of compressed air, the water was pumped down, after the caisson had reached its correct level, sufficiently low to admit of the air-tight floor being fixed. Divers were, however, previously employed to fix the stools on the sloping part of inner skin, and packings were inserted beneath to prevent further sinking of the shaft in consequence of the lowering of the water. Clay bags were also placed round the cutting-edge to prevent any ballast running in. When the air-tight floor was completed,

the water remaining inside was partly blown and partly pumped out, and the work of constructing the floor proceeded. An air-pressure of 35 lbs. to 37 lbs. per square inch, the highest employed on any part of the work, was necessary to dry the ground at the cutting-edge. Although this shaft was sunk within 6 feet of the river-wall previously referred to, no crack or settlement of any kind was caused.

The first 28 feet of No. 1 shaft were sunk in the same manner as Nos. 3 and 4, but on reaching this depth, large quantities of water were encountered, and the grab system was again used. This method was continued until the cutting-edge had passed through the ballast and sufficiently far into the clay below to cut off the top water. The water inside was then pumped out and manual labour was again employed. It was found, however, that the caisson was not sinking uniformly, owing, no doubt, to some part of the ground offering more resistance to the cutting-edge than others, and additional weight had, therefore, to be placed on the high side. The continual rocking of the caisson, due to its falling out of level and being corrected by weighting, no doubt broke up the ground to a certain extent, and, in addition, the shaft would probably carry down some ballast with it in sinking. The effect was a serious blow under the cutting-edge, and the shaft was again filled with water. As the air-tight floor was not in position, it was decided to provide a sump outside in order to lower the head of water, that inside the shaft being meanwhile allowed to rise. The sump was sunk to a depth of 34 feet, and the head of water lowered about 20 feet. The water in the shaft having been pumped out, preparations were made for constructing the floor as in shafts Nos. 3 and 4, but on clearing out the bottom, the ground was found to be too soft to support the weight of the caisson, which began to sink, although the packings were in position under the stools. The construction of the floor in the open was abandoned, and, on the completion of the air-tight floor (which had meanwhile been proceeded with), it was carried out under an air-pressure of 28 lbs. per square inch.

Although in uniform strata, such as that found in No. 2 shaft, the grab may be employed with good results, the control of the structure is imperfect, and it is extremely difficult to maintain it vertical in sinking. The same remark may apply to sinking without compressed air in variable material where water is encountered, because bad ground immediately becomes softened by the water and the caisson falls out of the vertical before measures can be taken to prevent it. With compressed air, however, the

difference between what is known as "good" and "bad" ground is comparatively slight; indeed, bad ground in the open is often excellent in compressed air.

In Nos. 1 and 4 shafts spiral staircases 6 feet wide are provided for foot passengers entering or leaving the tunnel at these points. No. 2 shaft is reserved for purposes of maintenance.

IRON-LINED PORTION OF THE TUNNEL.

The "cut-and-cover" portion of the tunnel already referred to was of a more or less ordinary construction, but the cast-iron lined portion, particularly that part under the river, was the cause of a great deal of consideration, both with regard to the actual sections to be adopted and the level at which the horizontal portion was to be constructed.

For about one-third of the distance across the river the tunnel had to be constructed through a bed of open ballast in direct communication with the river, and it was assumed that the pressure of air in this portion of the tunnel would have to be equal to that due to the head of water. It was not considered advisable for men to work in a pressure exceeding 35 lbs. per square inch above atmospheric pressure. This maximum air-pressure corresponds to a depth of 80 feet of water, and the bottom level of the tunnel was therefore placed at 80 feet below Trinity high water, or 67·50 below Ordnance Datum. The tunnel had to be of sufficient diameter to allow a line of traffic in each direction, and give two paths for foot-passengers. A diameter of 27 feet was considered the minimum which would give sufficient accommodation for the traffic, and the top was thus within 5 feet of the bed of the river in the deep channel, the ground between the top of tunnel and river-bed being open ballast. The experience gained in the construction of the tunnel showed that an air-pressure of 35 lbs. per square inch would have been unnecessary at a lower level, but any lowering of the tunnel increased the gradients on both sides, as the entrance on the north side was fixed by the East India Dock Road, and, on account of docks on each side, it was not possible to materially vary the line to any extent. The contract specified that all the tunnel between the end of "cut and cover" on the Middlesex side and No. 4 shaft was to be driven by means of a shield, and that compressed air was to be used over the same length. A shield was necessary to protect the face and roof in the portion under the river, and even in the portion on each side of it, where a

good deal of the excavation was in clay, it was equally necessary, as all subsidence of the ground had to be avoided.

Without the cast-iron lining a great portion of the tunnel would have been almost impossible. In addition to its necessity as a support, at once solid, from which to shove the shield forward, the following points are to be considered:—

(1) The work attains its full strength as soon as it is erected, and the difficulty in keeping pressure off green brickwork is avoided.

(2) The facility with which it can be erected. On some occasions 12 feet 6 inches of tunnel have been completed in 24 hours, and during that time only 7 hours was occupied in erecting the iron.

(3) A smaller thickness of lining is necessary than with brickwork, with correspondingly less excavation.

(4) The tunnel can be made absolutely water-tight from the inside by caulking.

(5) By immediately filling the space left by the shield at the back of the cast-iron lining settlement is rendered impossible.

Two sections of lining have been used, as shown in Figs. 7, 8 and 10, Plate 2, both 27 feet in external diameter. The first consists of a tube 2 inches thick, having flanges 12 inches deep and between 2 inches and 3 inches thick; and the second is 1½ inch thick, with flanges 10 inches deep and between 1½ inch and 2½ inches thick. The former was used from No. 4 shaft on the south side to No. 1 shaft on the north, and from this point to the railway, where the "cut-and-cover" construction commences, the lighter section was adopted. The rings of both sections are 2 feet 6 inches in length, and are built up of fourteen segments, about 6 feet long circumferentially, and a solid key at the top, together weighing about 14 tons 16 cwt., and 10 tons 10 cwt. in the heavy and light section respectively. All joints are machined and the segments are joined without any packing between them. Recesses are formed on the inside of the flanges for caulking, and the joints are thus made perfectly water-tight. Holes, 1½ inch in diameter, are drilled and tapped in each segment for grouting, and were closed with screw plugs when grouting was completed. The segments are fixed together with 1½-inch bolts of the various lengths required, each being provided with a grummet.

The deflection of the heavy and light rings under their own weight, when erected on the surface, was 2 inches and 2½ inches respectively, the maximum deflection when erected in the tunnel being 4 inches and 5 inches respectively. The castings were supplied by the British Hydraulic Foundry Company of Glasgow.

THE SHIELD.

The shield, which is constructed of steel, is shown in Figs. 13, Plate 3, and was designed by Mr. E. W. Moir, M. Inst. C.E. The problem which the contractors had to deal with in its design was complex, and the satisfactory completion of the tunnel shows the success with which the situation was met. It was known that the ground to be passed through consisted of clay, sand, and ballast, that there were probabilities of meeting large boulders, and that the hard beds forming the base of the London clay would be encountered. In London clay a shield with an open face was desirable, and one was required in which the whole or any part of the face could be closed in the ballast under the river channel. Provision had also to be made for the removal of boulders, trunks of trees, or other obstacles in front of the shield. Its strength should be sufficient to resist all possible pressure which might come on it either when compressed air was or was not in the tunnel and shield, or when there was compressed air in front of the shield and not in the tunnel. Sufficient strength was also required to take up the maximum pressure from the rams at the back when it was necessary to force it forward; bearing in mind the fact that the pressure of the rams might be more or less unequally distributed, owing to some rams being shut off at times in order to correct any deviation from line or level. In addition to these requirements every precaution had to be taken to ensure the safety of the men working at the face. The iron curtains hanging from the roof of each compartment were adopted with this object when it was intended to work with a higher air-pressure in the shield than in the completed tunnel; but even when this was not the case, the screen in the top pocket would keep a small amount of air in the tunnel in the event of a sudden inrush of water, provided the joint between the tail of the shield and the cast-iron lining was kept air-tight by clay or other means. Although the shield, as stated above, was designed to work with differential air-pressures at the face and in the completed portion of tunnel between the shield and the last air-lock, and also with differential pressures in the top and bottom of the shield, these methods of working were never adopted, and the different compartments of the shield were always kept open to the tunnel. It would be a great convenience, in a tunnel of large diameter, to be able to work with a higher air-pressure in the bottom than in the top compartments, but the difficulties in carrying this out are very great, and when most necessary, viz., in open ballast, they are greatest.

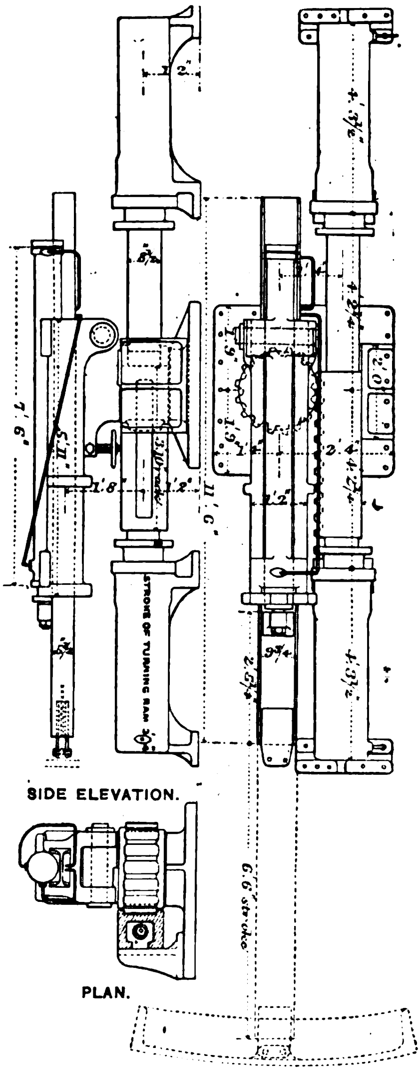
The total length of the shield was 19 feet 6 inches, and the outside diameter was 27 feet 8 inches. The outer shell or skin, $2\frac{1}{2}$ inches thick, consisted of four thicknesses of $\frac{5}{8}$-inch steel plates, twenty-eight plates extending the full length of the shield to each ring, and, consequently, all the joints were longitudinal. In some previous shields cross joints had been adopted, and the plates had been ripped up at these joints. The plates in the different rings broke joint with each other, and all the rivets were countersunk on the outside.

The first portion of the inner shell, beginning at 6 feet 8 inches from the rear end of the shield and extending forward for a length of 6 feet, was 24 feet in diameter, and consisted of a $\frac{5}{8}$-inch plate, the space between it and the outer skin forming cells for the hydraulic rams. The second portion was 25 feet 3 inches in diameter, and was made of $\frac{7}{8}$-inch plate. This portion takes up a certain amount of the thrust of the hydraulic rams, and is sloped down to meet the outer skin near the face, but the actual cutting-edge was formed of the outer skin only. The outer and inner skins were strongly braced together by circular girders; in the webs of the two rear of which holes were cut for the passage of the ram cylinders. The forward half of the shield was stiffened by three horizontal and three vertical plate diaphragms which also served to divide the working face into four floors and twelve compartments. There were two plate diaphragms, stiffened by vertical girders at right angles to the axis of the shield, one placed at about the centre of the shield, and the other about 3 feet behind it. These completely divided the working face from the tunnel if it were required to work with a higher air-pressure in the shield than in the tunnel, and four air-locks with rubber-faced doors, two on the first floor and two on the top floor, were provided for access to the face. They were, however, never required for working with a differential air-pressure, but were sometimes useful for closing the face. Access to the second and bottom floors was provided for by hatchways from the floors above, but in the case of the bottom floor two plates in the diaphragm were afterwards removed, and doors were fixed to allow of direct access from the tunnel.

An inclined spoil-shoot, fitted with rubber-faced doors at each end, was provided for each of the twelve compartments, but the doors, like those for the air-locks, were never required except for closing the face in emergencies. At 6 feet 7 inches back from the cutting-edge were placed the vertical iron screens previously referred to.

The rear end of the shield, for a length of 6 feet 8 inches, consisted of the outer skin only, and in this tail the tunnel segments were built. The tail was long enough to always envelop the last ring erected, even when the shield was shoved forward far enough to give room for the erection of the next ring. At the extreme end of the tail there was a bead or curved narrow plate extending round the inside. This allowed more working space for the adjustment of the ring to be erected, and at the same time permitted greater freedom in deflecting the shield if for any reason it was required to change its direction.

Figs. 14.



Scale, ¼ inch = 1 foot.

HYDRAULIC ERECTOR.

The number of hydraulic rams originally provided for advancing the shield was twenty-eight; they were 8 inches in diameter and had a stroke of 4 feet; but while driving through the wet sand and ballast under the river this number of rams was found insufficient, and was therefore increased by six other rams, 10 inches in diameter, but with a shorter stroke. The maximum water-pressure used was about 2¾ tons to the square inch, or a total, when all the rams were employed, of 5,165 tons, making no allowance for the friction of the rams. The pressure was obtained direct from

pumps on the surface, and the water was conveyed to the shield by a 1½-inch steel pipe, and distributed to the rams through copper pipes, each pair of rams having separate controlling-valves. The faces of the rams, where they abutted against the castings, were bevelled so that the thrust might be received on the outer skin of castings and not on the flange. The arrangement of packings and drawback in these rams has already been described.[1]

Two hydraulic erectors, *Figs. 14*, for lifting the tunnel segments into place, were carried on the back of the shield. The circular motion of the arm was obtained by a rack on a piston working vertically between two hydraulic cylinders which revolved a pinion on which the arm was fixed. A movable arm was lengthened or shortened by another jack fixed on the base of the arm, and a small movement in the plane of the length of the tunnel was obtained by a tangent screw near the pinion. A water-pressure of 1,000 lbs. to the square inch was used for working the erectors. The shield was built by Messrs. Easton and Anderson of Erith.[2]

Driving the Tunnel.

As it was of the greatest importance that the shield should be started to work with as little delay as possible, it was decided to erect it on the surface and lower it down No. 4 shaft as soon as the water-tight floor at the bottom should be completed. The weight of the shield without the hydraulic rams, &c., was about 220 tons, and it was decided to float it down; it was therefore built in a dry dock, Figs. 11, Plate 3, forming part of the cut-and-cover trench adjoining the shaft. The ends were close planked and caulked upon completion, and on a portion of the side of the shaft next the trench being removed the shaft and trench were filled with water. The shield floated on the depth of water in the trench reaching about 17 feet; it was then towed into the shaft, and, as the water was pumped out, it sank until it reached the timber cradle previously prepared for it at the bottom.

After the shield had been placed in the tunnel opening of No. 4 caisson (in which cast-iron guides had been bolted to ensure true line and level being followed), a portion of the cast-iron lining, extending to the other side of the shaft, was temporarily built up behind the shield to form an abutment for the hydraulic rams in driving the shield forward. It now became

[1] Minutes of Proceedings Inst. C.E., vol. cxvii. p. 27.

[2] A model of the shield, kindly lent by the London County Council, was exhibited.

necessary to remove the plug from the tunnel opening; in doing so a commencement was made at the bottom, and as the girders carrying the bottom outside plates were removed the latter were temporarily strutted to the shield. Clay, chiefly in bags, was then built against the plates to support the face when they should be taken out. The second row of plates being similarly dealt with, a sufficient height was obtained to draw out the bottom row by means of a tackle or union screw; the same process was continued with the other plates until the whole of the plug was removed and replaced by a wall of clay, through which the shield was driven into the face beyond. This method of removing the plug refers more particularly to that adopted in gravel, &c.; when the face consisted of clay such extreme care was not necessary. The ground in front of the plug was sometimes grouted with cement before the plug was removed. The strata on starting from No. 4 shaft consisted of 1 foot of sand at the bottom overlaid by 25 feet of London clay with about 1 foot of ballast showing at the top. The latter, as previously stated, had been drained to a large extent by the pumps for the adjacent "cut-and-cover" work, and, as it was known that on account of the gradient of the tunnel the ballast would soon disappear, it was decided not to use compressed air at the outset, but to drive a top heading to deal with the gravel and water. The water was strongly impregnated with creosote oil, &c., from a tar distillery above, and considerable pain and inconvenience were felt by the men through inflamed eyes, and burnt hands and arms; this trouble, however, passed away as soon as the clay was sufficiently thick to cut the water off, after which the top heading was discontinued.

At first progress was somewhat slow, only 125 feet being driven in the first two months, but after the gravel disappeared and the top heading was discontinued, better progress was made, an average length of 25 feet being completed per week. An accident, however, soon after happened to the shield which caused some delay. At the base of the London clay, and in the sand immediately below it, large pieces of rock were embedded and considerable damage was caused to the cutting-edge by driving against them. This was first discovered after fifty-four rings had been erected, and, although great care was exercised in clearing the excavation in front of the upturned part of the cutting-edge, the damage continued to increase, and, after another twenty-six rings had been erected, the shield was found to be unworkable. As it was not practicable to repair it in its then position, it was decided to construct a concrete cradle for it to slide upon. A timbered heading, 19 feet

wide, was therefore driven and kept about 50 feet in advance of the shield, so that the concrete should have time to become hard before the shield came upon it. During the driving of this heading trouble was again experienced from water in the ballast above finding its way through cracks in the clay, and the top heading was accordingly recommenced, so as to intercept the water and carry it through the shield. This method of working was continued until No. 3 shaft was reached, where the repairs to the shield were effected.

Until about 490 feet had been driven towards No. 3 shaft no great quantity of water was met with, but at that point a large volume suddenly broke into the bottom heading. Considerable difficulty was then being experienced in sinking No. 3 shaft, and the water which broke into the heading undoubtedly came from the ballast, and found its way either down the side of the shaft or through the cracks in the clay which had been caused by the numerous blows. As the shield was then only 67 feet from the shaft (the bottom of which was to be 15 feet below the invert of the tunnel) it was deemed prudent to suspend any further tunnelling operations until the shaft was sunk to its full depth. Meanwhile No. 1 bulkhead was built. It was constructed of concrete 12½ feet thick, having two locks at the level of the temporary tramway, fitted with rubber-faced doors. Two sets of outlet- and inlet-cocks were provided, one, 2½ inches in diameter, for use when the locks contained materials only, and the other, 1½ inch in diameter, when men were passing through. The various pipes for compressed air, hydraulic pressure, blow-out pipes, &c., were built in as shown in Figs. 15, Plate 3. The inner, or pressure, side of the bulkhead was rendered with cement, and any small spaces between the brickwork and the tunnel-lining, caused by settlement, were grouted up through pipes built in for the purpose, and by these means no difficulty was found in making the wall air-tight. In the three bulkheads which were afterwards constructed for other portions of the work, brickwork was substituted for concrete as being more easily removable, and a smaller lock, 3 feet wide, called an emergency lock, built in near the top of the tunnel, was added. No. 3 shaft having been sunk to its full depth, tunnelling operations were resumed as soon as the bulkhead was completed, the remaining length of tunnel from this point to the shaft being driven under compressed air.

A fire which occurred in the top heading on this portion of the work caused considerable anxiety. It was feared that the escaping compressed air might carry the flames through the ground saturated

with very inflammable material to the distillery above, in which case a serious conflagration would have resulted. Happily a good supply of water was at hand, and the fire was extinguished before any such accident happened.

The air-tight floor was fixed and pressure applied in the shaft when it was required to drive the shield through the tunnel opening.

On the arrival of the shield at No. 3 shaft it became necessary to undertake the repairs required on account of the buckling of the cutting-edge. It was decided to cut away the distorted portions of the skins and vertical stiffener, *Figs. 16*, and substitute heavy steel castings, as shown in Figs. 17, Plate 3. At the same time the projecting plates of the undamaged part of the cutting-edge were cut off, and, although sharpness was thereby lost, the edge was much stronger to sustain a blow against any obstacle in front. The steel castings were made to a larger radius than the outside

Figs. 16.

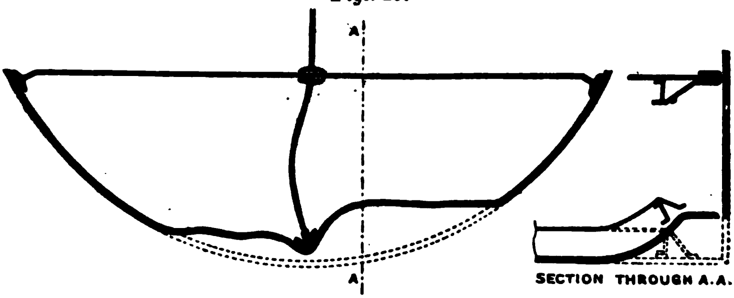


DIAGRAM SHOWING DAMAGE TO THE CUTTING-EDGE.

skin, so that they should stand "proud" of it and thus decrease the skin friction when the shield was being pushed forward. A steel band, ⅝ inch thick, was also carried round the outside of the undamaged part of the cutting-edge, with the same object, and to further strengthen it. Most of the repairs were executed in the ordinary atmosphere; they were commenced on the 28th May, and completed on the 25th August, thus extending over a period of thirteen weeks. In carrying out the repairs a great number of holes had to be drilled, and flexible shafts driven by electric motors were used to great advantage. The motors were fixed in the shield and current was supplied from dynamos on the surface.

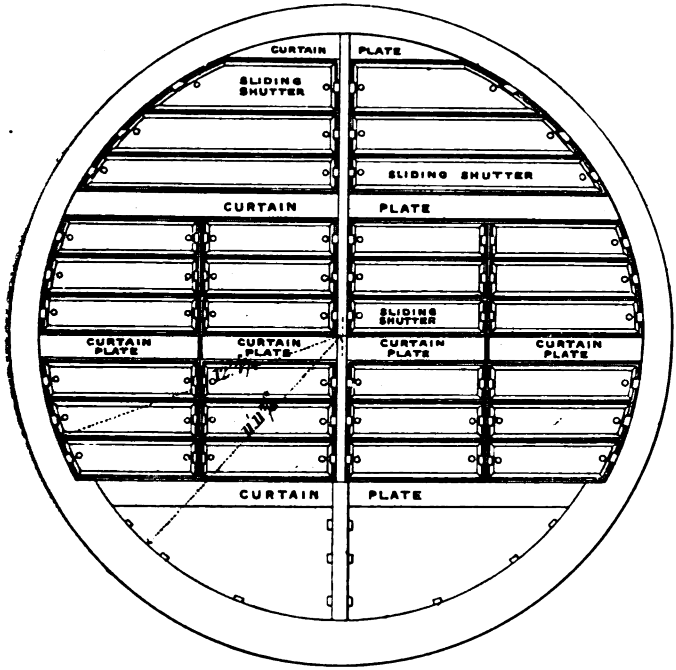
Under the River.—The portion of the tunnel between No. 2 and No. 3 shafts includes all the work actually beneath the Thames. The length from centre to centre of the shafts is 1,222 feet. There is a layer of London clay between the tunnel and the river-bed for

nearly three-fifths of the distance; the clay is then lost, and what was probably an older and deeper bed of the river, now filled with ballast, was met with, Fig. 1, Plate 2. As was anticipated the work was carried out expeditiously, and without difficulty in maintaining a sufficient pressure of air as long as the clay cover continued. In starting from No. 3 shaft the upper part of the shield was in clay and the lower part in sand. The latter would, without air-pressure, practically be a quicksand, but with compressed air it formed most favourable material. It was more or less stratified and interleaved with thin beds of shale, so that the face would stand with practically no timbering, only an occasional face-board being required. It was very fine and close, and consequently there was little escape of air. The rate of progress here surpassed that in any similar tunnel yet constructed. In two months, more than 500 feet of tunnel were completed, and occasionally five rings, or a length of 12 feet 6 inches, were constructed in 24 hours. During a day, therefore, 300 cubic yards of material was excavated, and about 75 tons of cast iron erected. When it is considered that these materials, in addition to lime, other necessaries and empty wagons, had to pass through the air-locks, it will be apparent that very careful organization on the part of the contractors was required. The bricks, sand, &c., for No. 2 bulkhead, which was built under the river at a distance of about 220 feet from the shaft, had also to be brought in during this time. As the tunnel approached the centre of the river the lower part passed through mixed deposits, such as thin beds of clay, clay and shells, chalk and greensand. The excavation of the chalk required more time than that of the sand, but still the progress was well maintained, and in 11 weeks after starting from the shaft half the distance across the river was completed. When 700 feet had been driven, ballast appeared in the top, and it was decided to stop to fix the shutters at the face of the shield, so that as much or as little of the face could be closed as required to prevent undue loss of air and any sudden rush of ballast.

In penetrating the old river channel the shield passed within about 5 feet of the bed of the river, the material above being open ballast. Previously to reaching this point permission had been obtained from the Thames Conservancy to tip a temporary layer of clay on the river bed for a length of 450 feet in the line of tunnel. Its maximum depth was 10 feet, and it extended 75 feet on each side of the centre line. It offered resistance to the air escaping from the tunnel through the open ballast, and its weight prevented the bed of the river from being blown up by the

pressure. The clay was deposited from hopper barges, and was removed as the tunnel was completed. The Authors wish to take this opportunity of testifying to the anxiety of the Conservators and of their Engineer, Mr. C. J. More, M. Inst. C.E., to facilitate the execution of this part of the work in every way, consistently with a due regard to non-interference with the river traffic. It

Fig. 18.



Scale, ¼ inch = 1 foot.

SHUTTERS AT THE FACE OF THE SHIELD.

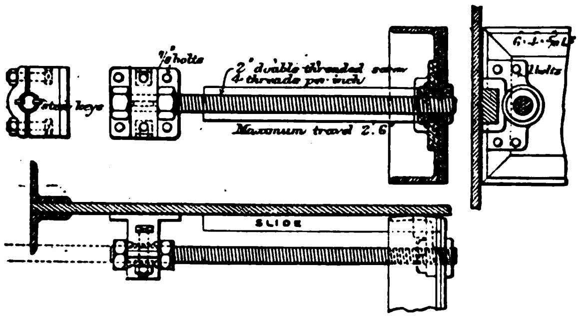
may be said that without this concession the tunnel would probably still be far from completion.

The shutters for closing the face of the shield, *Fig. 18*, were invaluable when passing through ballast or any open material. As the face had to be kept closed while the shield was being moved forward it was evident that they must have a sliding movement, so as not to become broken up when the shield was advancing, as would be the case if the face was timbered in the usual way. In each compartment of the three upper floors there

were three shutters; they varied in depth between about 2 feet 3 inches and 1 foot 6 inches, and were of varying lengths to suit the different compartments. Each consisted of a $\frac{5}{8}$-inch iron plate, stiffened at the edges by heavy angles, and sliding on guides fixed to the sides of the compartment. The shutters were controlled by long screws, *Figs. 19*, fixed to their ends and extending through bearings on the side of the compartment. There were two slots machined the whole length of each screw, and two keys in each bearing ran in these slots, thus providing a means of graduating the rate of movement of the shutters if necessary. Two nuts running on the screw, one on each side of the bracket, made it possible either to shove forward or draw back the shutter.

In the ballast, previously to shoving the shield forward, the

Figs. 19.



Scale, $\frac{1}{4}$ inch = 1 foot.

SCREWS CONTROLLING THE SHUTTERS AT THE FACE.

face of a compartment was completely closed by its three shutters which had been screwed forward as close to the cutting-edge as possible, the shutters being directly over each other, and the small space between them being filled with clay. When the shield was to be shoved forward the nuts on the screws were loosened on the forward side of the bearings allowing the shutters to move back as the shield was shoved forward. Any sudden movement was guarded against by running the nut only 1 inch or so in front of the bracket at a time. If the ground was very loose, and, consequently, the air escaped quickly, a man in each compartment kept the spaces between the shutters filled with clay, the rate of travel being sufficiently slow. The movement of the shutters was nearly double that of the shield, as their area was considerably less than that enclosed by the cutting-edge. After the shield had

been shoved as far as required, the shutters would be considerably behind their former position, the space in front of them being filled with ballast. The method and rate of removal of this material depended on the consistency of the ballast, and whether the air-pressure in the tunnel was sufficiently high. Under favourable circumstances the ballast might be shovelled out from the top of the shutters, or a shutter might be drawn somewhat further back and the material shoved out between that shutter and the next lower one; but in any case the top shutter was first excavated and screwed forward and then those at the middle and bottom. When the gravel was very coarse, and other circumstances unfavourable, all the ballast in front of the shutters was scraped out by small iron rakes or by hand through holes 7 inches by 4 inches in the shutters, which were furnished with sliding doors, the greatest care being taken to open as small an area of the face as possible, and each shutter being screwed up as the stuff was excavated. It is not surprising that when working in this way, which was often necessary for safety, the progress was sometimes only 1 foot per day. The amount which the shield was shoved forward at one time varied greatly; sometimes only a few inches could be obtained, but in clay the length necessary for a complete ring was occasionally completed.

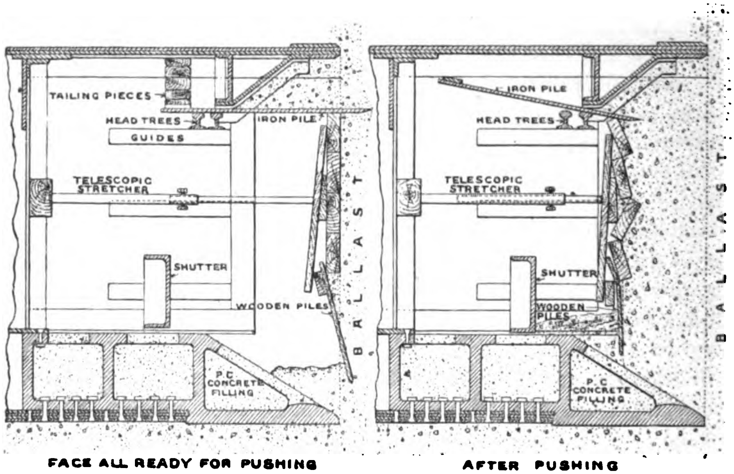
While driving through the ballast the cover above the tunnel was so small and of such a character that sufficient pressure could not be maintained to dry the ground at the invert; and as the river was then in direct communication with the face a large and constant stream of water found its way into the bottom floor of the shield. It was dealt with by blow-out pipes, four 5-inch pipes being generally necessary for the purpose. These pipes had flexible hose terminations at the shield, and the water was blown out into the finished part of the tunnel behind the bulkhead and thence pumped to the surface.

The sliding shutters were not used in the two bottom pockets, and in their place a combination of long horizontal iron piles and short vertical timber piling, *Figs. 20*, was adopted. By this arrangement it was possible to clear out the ballast up to the cutting-edge, which could not be done with the shutters. Great difficulty was experienced in the bottom floor, and the men working here were generally standing in about 18 inches of water throughout the day. Perforated tunnel-plates were occasionally built in to relieve the water at the face by allowing it to enter the tunnel further back. Jets of high-pressure water were used at times at the face to keep the material moving while the shield

was advancing, to diminish the pressure required to shove the shield forward. Small shots were also used to shake the ground and to remove any hard material; and a man was constantly employed testing the face with a bar in front of the shield to discover any large boulders which might damage the cutting-edge.

The difficulties encountered while driving through ballast suggest modifications in shields for tunnelling similar material. The shutters should be placed as close as possible to the cutting-edge,

Figs. 20.



Scale, ¼ inch = 1 foot.

TIMBERING IN THE LOWEST SECTION OF THE SHIELD.

and their area in relation to that of the face should be as large as possible. Much of the difficulty in driving the shield was due to this difference of areas; it would probably be little felt in passing through soft material which flows easily, but in gravel the resistance from this cause is very great. Such modifications would probably necessitate a heavier shield, but great improvement in working would result. It would also be well to allow for a large increase in the power required for shoving the shield over that anticipated, as it is difficult to even roughly estimate it when it is necessary to work with a closed face.

An air-tight hanging screen was always fixed a short distance behind the shield to ensure the safety of the men. It reached down to the centre of the tunnel, and was fitted with an air-lock at the top, the doors of which were hung to open towards the

bulkhead; this could be reached by a gangway which was added to as the shield advanced. In the event of an inrush of water, the men could thus escape to the other side of the screen, where they would always find an air-space, and thence, by a gangway, to the emergency lock in the bulkhead.

Serious "blow outs" occurred while working in the ballast, and on two occasions the air-pressure fell so suddenly, and the water from the river poured in so fast in the two upper floors, that the tunnel was flooded to a depth of 7 feet or 8 feet in a few seconds. The first of these blows occurred on the 30th April, 1895, and the second and largest about a week later, when about three-quarters of the distance across the river had been covered. The escape gangway had not at that time been provided, and, owing to the dense fog, caused by the sudden fall of air-pressure, completely obscuring the electric lights, the men had difficulty in escaping back to the lock, then distant about 700 feet. The clay which had been placed on the bed of the river was then of the greatest possible value; it followed down upon the ballast, which was washed in by the water as through a funnel, and choking the passage the air-pressure soon increased. The immediate cause of these accidents would appear to have been the breaking down by the rising tide of a large area of the hard crust on the river-bed left unsupported by runs of ballast from beneath it. Great care was afterwards taken to look out for and fill such cavities with sawdust; this material was found to be very convenient for the purpose, the escaping air carrying it into the cavity through the hand-holes in the sliding shutters. It will be noticed that for a length of 190 feet the river-crust continued to break away, and allowed the clay, deposited on the river-bed, to enter the shield; but as long as there was no cavity, and consequently no liability of a large area of crust suddenly giving way, no danger was to be apprehended. In addition to carefully watching for cavities in the front of the shield inside the tunnel, soundings were taken in the river in front of the shield every day to discover any subsidence of the clay. A delay of several days was caused by the great frost in the early part of 1895. It had been ascertained by soundings that a depression existed in front of the shield, which it was necessary to fill before continuing driving; but as the clay was frozen in the barges, and the navigation of the river was impossible on account of ice, operations had to be suspended until the weather moderated. Although the cover above the tunnel increased as progress was made towards the north bank, extreme care was necessary throughout,

and it was a great relief to all connected with the undertaking when No. 2 shaft was safely reached. The progress at one time did not amount to more than 5 feet per week, but this was increased to about 20 feet as the shaft was approached, and the men became more accustomed to the work. The cutting-edge of the shield touched No. 2 shaft fifty-four weeks after the first ring was erected in No. 3 shaft.

Before removing the plug in the opening of No. 2 shaft, iron piles were driven from the inside of the shaft over the top of the shield, provision for this having been made in building the plug. The work of driving the shield into the shaft was then comparatively easy. The shield was found to be in as good condition as when it left No. 3 shaft, which, considering the severe treatment it received on its journey, speaks well for the excellence of its construction.

The air-compressing plant, boilers, &c., were taxed to their utmost capacity during most of the work through the ballast, some of the compressors working with scarcely a stop for twelve months. Considerable repairs were consequently necessary before the tunnel beyond No. 2 shaft could be proceeded with. They occupied some weeks, and the contractors took the opportunity during the suspension of work to invite a number of visitors to celebrate the accomplishment of what must be considered the most difficult piece of subaqueous tunnelling ever undertaken, luncheon being provided in the tunnel about midway across the river.

No. 2 Shaft to Railway.—Early in December work was resumed; the shield having been placed in position in the tunnel opening on the north side of the shaft, and the temporary iron lining built behind to take the thrust of the hydraulic rams, the air-tight floor, which had been partly removed, was again closed, the air-pressure applied, and the plug removed. The face at this point, as under the latter part of the river, consisted entirely of ballast fully charged with water; the same difficulties were therefore met with both in removing the plug, and, for some distance, in driving the tunnel, necessitating almost the same caution. Beyond small subsidences near the shaft, however, no accident occurred, and No. 1 shaft was reached on the 10th April. A slight delay was occasioned at this point by the difficulties referred to in constructing the bottom floor of the shaft, but by the middle of May the shield had passed through and had been adjusted to the new line to be followed to join the cut-and-cover portion at the railway. A distance of about 800 feet remained, and it was accomplished by the end of September of the same

year. Much difficulty was experienced in this length in maintaining sufficient air-pressure to dry the face, numerous cracks appearing in the surface, through which the air escaped with great rapidity. On one occasion a fissure larger than usual caused a serious "blow out." The pressure in the tunnel fell suddenly from 7½ lbs. to 3½ lbs. per square inch, and the outflow of air was so large that the workmen's shirts, which they had removed for working, together with empty bags and a waistcoat, were carried up through the fissure and blown into the air above. The cover at the point where this occurred was about 19 feet. The waistcoat contained half a sovereign, which the owner was afterwards fortunate enough to recover. A chimney shaft, 150 feet high, about 60 feet distant from the side of the tunnel, the foundation of which was built in gravel 20 feet above the invert of tunnel, occasioned some anxiety. The structure was, however, passed without damage. Another blow out occurred later while working under the rails of the Great Eastern Railway, where all the air was lost. The cover at this point is about 2 feet, and the pressure had been reduced to about 2½ lbs. per square inch. In the remaining 30 feet no attempt was made to raise pressure again, and the length was constructed under normal conditions.

All the cast-iron portion of the tunnel is lined with 4 to 1 Portland-cement concrete, and faced with white glazed tiles 9 inches by 3 inches to preserve uniformity of appearance with the brick facing in the cut-and-cover portion of the work. Throughout the cast-iron lined tunnel and the cut-and-cover, the roadway is carried on a 9-inch brick arch levelled up with concrete as shown in Fig. 10, Plate 2. The subway thus formed gives ample room for two large water-mains, or for a ventilating trunk, if necessary. Provision is made for ventilation by building in at intervals pipes 2 feet 6 inches by 4 inches following the curve of the side of the tunnel and having an opening at the crown. These pipes are continued downwards to the subway under the road where they can be connected to a main ventilating pipe which can be exhausted by fans at shafts Nos. 2 and 3. The width of the roadway is 16 feet throughout, and there is a 3-foot footpath on each side of the tunnel, increased to 5 feet 3 inches in the open approaches. The gradients of the approaches are 1 in 36 and 1 in 34 on the Kent and Middlesex sides respectively. The drainage of the roadway is taken by gullies 50 feet apart on alternate sides, and from thence it is conducted by 6-inch and 9-inch pipes to No. 2 shaft, and there it is pumped to the surface. The roadway for the level portion of the tunnel under the river is of

asphalt, and for the approaches on each side granite setts laid in pitch and tar, the gradients on the latter portions being too steep for asphalt. For ordinary cart traffic access to the tunnel can only be obtained at the ends; but for the convenience of pedestrians stairways are provided at four other points, viz., at the junction of the "cut-and-cover," and "open approach" on each side of the river, and at Nos. 1 and 4 shafts.

With shafts of such a large diameter as those adopted there was no difficulty in setting out with accuracy the line of the tunnel from shaft to shaft. Two points in the centre line were fixed in the shaft about 30 feet apart before the air-tight floor was fixed; these points were below the floor and above the level of the tunnel. After the tunnel was driven through the shaft to some distance on the other side, the line was transferred into the tunnel from these points before a new bulkhead was built, and a good base was thus obtained. Each pair of hydraulic rams was controlled by a separate valve, so that, with careful watching as the shield advanced, it was possible to keep it accurately to line and level.

All the spoil from the tunnel was raised to the surface at either No. 4 or No. 2 shaft. The material from the two bottom floors of the shield was cast out on to the temporary floor in the tunnel and then filled into wagons; that from the two top floors was cast on to a temporary platform travelling behind the shield from which it was filled into the wagons directly below through vertical shoots. All the haulage was by endless ropes driven from winches worked by compressed air. The wagons were taken up the shafts in cages and tipped either into the large wagons which conveyed it to form the approach roads on the Kent side, or shot directly into barges for disposal elsewhere.

MACHINERY.

There were six air-compressors, of a total capacity of about 1,500 HP. The two largest, of about 300 HP. each, were manufactured by Messrs. Walker Brothers, of Wigan; two were made by the Ingersoll Company, of New York; one by the Haslam Engineering Company, and one by Messrs. Slee. A smaller compressor was also in use for the air required for grouting purposes. During a large portion of the time, while passing through loose ballast, as much as 10,000 cubic feet of air per minute was sent into the tunnel. It was carried into the tunnel by steel-riveted pipes 8 inches in diameter, taken down No. 4 shaft,

on the Kent side, and thence along the tunnel as completed to the end at the Middlesex side. When the air was escaping freely at the face, the amount pumped through these pipes was very large, and the velocity consequently very high. On this account the difference between the air-pressure in the engine-house and in the tunnel sometimes showed a loss of 40 per cent. It is evident that for a long tunnel it would be economical to have pipes of ample size, so that the velocity of air could be kept at say about 30 feet per second, as the extra cost of pipes would soon repay itself. The air for grouting purposes, the pressure of which was about 40 lbs. per square inch greater than that for the tunnel, was carried in a 5-inch pipe. The high-pressure water for the rams was carried in a steel pipe 1¼ inch in diameter, and as the end of the pipe was connected with the moving shield, a "walking joint" was used at some distance back from the face.

The travelling platform alluded to was 40 feet long, and nearly the full width of the tunnel; it ran on rails fixed to brackets on the tunnel castings, and, being attached to the shield, moved with it. There were three floors, so that all parts of the tunnel, except that immediately beneath the temporary roadway, could be reached for the purposes of grouting and caulking. This platform carried the grouting-pans and all materials necessary for caulking and grouting, and it received in the first instance the spoil from the two top floors of the shield.

The grouting was, as a rule, not carried close to the face, but was kept a few rings back, as difficulty was experienced in preventing it from leaking into the tunnel between the tail of the shield and castings. The difficulty of the grout blowing into the shield has been overcome in smaller tunnels by placing wooden curbs, faced with rubber, in front of the last ring and held in position by the hydraulic rams. This method was tried at Blackwall, but it had to be abandoned on account of the delay it caused. Several pushes were often required before sufficient advance was made for a 2-foot 6-inch ring, and, as timber would not support such a pressure as that used, the curbs had to be taken down before, and re-erected after, each push. The grout also collected in front of the bead inside the tail of the shield, and ran along outside when working in ballast, considerably increasing the resistance to advance. As a substitute for the curbs a pneumatic collar was tried placed in front of the bead, between the lining and the tail of the shield, which would adjust itself to any variation in the clearance. Although for some time this promised a solution of the difficulty, it had to be abandoned after several

had been destroyed and left behind. Neat lias lime was used for all the grouting. In clay a complete band was obtained round the outside of the castings, and in gravel, although this came down at once as the shield advanced, a large quantity of lime was used, probably forming a kind of concrete around the castings. When fine sand was met with it was very difficult to force any lime outside the castings at all.

The rust-joint caulking, with the exception of that under the temporary road, was carried out as the work proceeded. The first lengths of the caulking were not satisfactory, but after experimenting with different proportions of materials, the work was made water-tight. The mixture adopted was ½ lb. of sal ammoniac to 100 lbs. of iron borings, and in wet joints soft lead was first caulked in to keep water-pressure from the rust joint until it had set.

Electric incandescent lamps were used for lighting throughout the construction of the work to avoid vitiation of the atmosphere by lamps or candles as much as possible. An electric-light installation has been erected on the Middlesex side of the river for the permanent illumination of the tunnel, and also to supply current for working the drainage pumps and a small lift in No. 2 shaft. The tunnel will be lighted by three rows of incandescent lamps of 32 candle-power, fixed 10 feet apart, on alternate lines, with additional lamps and a few arc-lights in the shafts. The open approaches will be lighted by groups of incandescent lamps.

The London County Council showed great interest in the health of the men employed in compressed air; and a stringent clause was inserted in the contract specifying, among other particulars, proper ventilation at the working face, the provision of lifts and resting-places for the men, including a compressed-air chamber fitted with locks, and that no workman should be engaged for compressed-air work without his fitness for such duties being proved by previous experience or by medical examination. After the commencement of the work the Council obtained parliamentary powers to compensate men who might be injured by working in compressed air, although the men were not employed directly by the Council. A resident medical officer, Dr. E. H. Snell, was also appointed to examine all men previous to working in the compressed air, or who might be injuriously affected by it, and to thoroughly investigate the nature of compressed-air illness. The cases of illness due to compressed air were few, and only three cases of permanent illness have been attributed to this cause, and there were no deaths. This is probably due to the fact

that a sufficient supply of air was delivered, and that the men did not work in too long shifts. The general period of work was 8 hours, but there was a break of $\frac{3}{4}$ hour in this time as near the middle as possible. Hot coffee was supplied by the contractors to the men in the middle of their shift, and also before coming out; and proper drying rooms with lockers were provided for their clothes.

Cost.

The cost of work of this class is naturally of great interest; but the risks incident to tunnelling in gravel within a few feet of the bed of a navigable river must generally render the contract cost of such works of uncertain value.

The cost of the completed work, as contracted for by Messrs. S. Pearson & Son, was £871,000, and, although there were some alterations from the contract quantities, the actual cost was below this amount. The contract price for heavy cast-iron section was £126, and that for the light iron section £105 per lineal foot, the internal lining and roadway not being included in either case. The cost of the cut-and-cover portion, ranging in depth between 34 feet and 42 feet, was £59 per lineal foot; and for the portion ranging in depth between 42 feet and 65 feet, £105 per lineal foot, the roadway not being included in either case. The cost of the open approaches, of an average depth of 35 feet below the surface, was £37 per lineal foot, exclusive of the roadway.

The work was designed, as previously stated, and carried out for the London County Council by their Engineer-in-Chief, Mr. Alexander R. Binnie, M. Inst. C.E.; Sir Benjamin Baker, K.C.M.G., Past-President Inst. C.E., and the late Mr. J. H. Greathead, M. Inst. C.E., being consulted on several matters. The contractors were Messrs. S. Pearson & Son, whose representative and engineer on the work was Mr. E. W. Moir, M. Inst. C.E., who was responsible for the design of most of the special appliances used. The Authors acted as joint resident engineers in charge of the work on behalf of the London County Council.

The Paper is accompanied by drawings, from which Plates 2 and 3 and the *Figs.* in the text have been prepared.

Discussion.

Mr. Preece. Mr. W. H. Preece, C.B., Vice-President, moved a vote of thanks to the Authors for their valuable Paper, which was carried by acclamation.

Mr. Moir. Mr. E. W. Moir observed that in designing the caissons for the shafts, he had allowed a batter of 1 in 100 on the outer skins; but he thought that was too great, and if he had to repeat the work he should prefer a batter of say 1 in 300, or a parallel piece, between 20 feet and 30 feet deep. He thought there would be less difficulty in keeping the caissons vertical if they had been so made. He had computed the strength of the concrete floor at the bottom on the basis that it concealed a dome within its thickness. The designing of the air-tight floor used in three of the shafts had caused much trouble, the reaction at the ends of the main girders being about 400 tons. That reaction had to be transmitted to the caissons by attachments to the inner ½-inch, and the outer ⅜-inch skins. He had found that the inner skin alone had not the necessary strength to transmit the reaction sufficiently far round the shell to give the necessary shear area between one course of plates and the next below it. It was therefore necessary that the doubling plates mentioned should be added to the inner shell of the caisson, thereby insuring such a small vertical deflection that the rivets along a great length of seam acted together. He had allowed for as much ballast upon the floor as it would carry without air-pressure below it, the upward load being reduced by that amount. Water-ballast had been used; it helped to retain the air where the temporary bolting leaked, and was quickly increased and reduced. The erectors attached to the back of the shield had worked well, but on another occasion he would adopt two hemp-packed cylinders for pushing out and pulling in the telescopic girder, instead of one with double leathers, which were more trouble to keep in order than common glands. Double leathers inside a hydraulic jack always gave trouble; they were out of sight, and if they failed the whole machine had to be pulled to pieces to reach them. Hemp-packing with common glands was much more serviceable in ordinary work. In designing the erectors he had allowed a margin of 50 per cent. in the power of the telescope cylinder, and 60 per cent. in the turning cylinders. He might with advantage have increased that

allowance, as sometimes the power was reduced owing to leaky slide-valves, the surfaces of which would always wear. The shortest time in which a complete ring of fourteen segments and a key, weighing about 14 tons, had been erected, was thirty-five minutes. While passing between No. 1 shaft and the railway on the Middlesex side the ground had been found too dry. About 18 inches of water had therefore been pumped on the surface, which, passing down, had closed the cracks in the dry ground, the head of water in each crack preventing the air escaping. When driving the tunnel through clay, practically watertight silt or fine sand, no difficulties were experienced. As to the ballast, however, it had early been decided to place a blanket of clay at the point where the tunnel approached so near the river-bed. If the Thames Conservancy had found it impossible to allow the river-bed to be raised, it had been intended to dredge a channel and fill it again with puddle. With only 5 feet of ballast and 10 feet of clay, there was greater safety than with 15 feet of ballast and 5 feet of clay, the reason being that with a thick bed of ballast the amount of clay placed upon it was not sufficient to fill the cavity formed by a "run," and the clay on the edges of the hole would break away and allow the air to escape. The width of the clay blanket had been fixed at 150 feet, so that the air, when it bubbled out of the face of the shield, collected in a lump under the clay blanket, and as it had to run off at some kind of a natural slope, the nearer the blanket was to the top of the shield, the lower down the face did the air-bubbles come, and they slanted off, gradually getting nearer the clay as they approached the edge. He therefore did not think the width was excessive. It had been decided from the first not to attempt to dry the ballast face to the bottom, because an air-pressure sufficient to dry the whole face would have blown off the roof. He had had some experience of that in America; it was therefore decided to vary the air-pressure according to the tide to balance approximately the hydrostatic head at the top of the shield. In that way, as long as there were 10 feet of clay above the tunnel, a blow-out had never occurred. The first blow-out was due to the fact that the thinner portion of the artificial covering was being approached. The gravel ran out from below the clay, which was only a few feet thick, and was suspended on a cushion of air. The clay broke through, the air burst out, and in came the water. The Thames Conservancy, through their engineer, Mr. More, recognised that such was the case, and allowed the filling to be increased to 15 feet. He was afraid that had been exceeded, for Mr. Moir.

Mr. Moir. one morning he had noticed a ship stranded on the clay bank for a short time. The bulkheads, which were composed of 12 feet 6 inches brickwork, he had designed on the same basis as the bottom of the caisson, viz., on the assumption that they concealed a dome. They could not be treated as beams, because there was no tensile resistance between the side of an iron lock and a piece of brick masonry; but the concealed dome seemed to be the correct method of calculation. He might be permitted to draw attention to the lock doors, which were hollow. The area of each door was 20 square feet, 5 feet by 4 feet, which was very large. They were composed of two $\frac{5}{16}$-inch steel plates buckled. He had had them tested, before they were delivered, to 50 lbs. per square inch, and there was no measurable deflection. The outside shell of the lock was 7 feet in diameter, the plate being only $\frac{3}{8}$-inch thick; the locks were therefore always built projecting on the atmospheric side, so that there should only be tension in the outer skin of the lock. The thin steel shell was never in compression. Reference had been made in the Paper to the small amount of illness arising from compressed air. The freedom from disease among the men employed under air-pressure was no doubt due to the experience he had gained in the Hudson Tunnel, where the compressed air-lock, for re-immersing men who were overcome on coming out, had been used for the first time. He had also, from the commencement, at Blackwall, had samples of the air taken; these were analyzed by one of his assistants, Mr. Collingridge, a brother of Dr. William Collingridge, Medical Officer of Health for the Port of London, who gave valuable hints as to the methods adopted. Whenever the amount of carbonic acid increased above 1 part in 1,000, the speed of the engines was increased. The impurity of the air was found not to be dependent upon the amount delivered per man per hour as gauged by the speed of the air-engines. Sometimes it was comparatively pure when a much smaller quantity was being delivered than was required at other times. That, he imagined, was due in some measure to the lime used for grouting in the tunnel making lime-water, which absorbed some of the carbonic acid. At another time, when some 10,000 cubic feet per man per hour were being pumped, and when it was thought the air must be very pure, some of the oldest hands began to complain of pains, though the pressure was only about 15 lbs. per square inch. Samples were taken, and the carbonic acid was found to have increased to 3 parts in 1,000. That was due, no doubt, to the fact that the tunnel was passing under what had been the Isle of Dogs' sewer, and the earth was giving off car-

bonic acid. The purity of the air must increase with the increase of pressure. Another case had confirmed the ill-effects of carbonic acid. The general air in the tunnel was good, and about 6,500 cubic feet per man per hour were being pumped; but, notwithstanding, in the right-hand bottom compartment of the shield, cases of caisson disease were constantly occurring. He could not understand it for some time, but when a particularly bad case occurred, a foreman miner being sent to the hospital, he had discovered the cause. In order to ease the shield while it was being pushed forward, charges of tonite were fired in that particular compartment, and the carbonic acid given off by its combustion and that of the fuse, raised the quantity of carbonic acid above the healthy limit at that pressure, namely, to 1 part per 1,000; and there could be no doubt that that was the cause. The analysis of samples of the air to test its purity had been commenced in the tunnel in May, 1894, six months before the appointment of the special medical officer. Mr. Moir.

Dr. E. H. SNELL had had the honour of being appointed by the London County Council, Resident Medical Officer to the Blackwall Tunnel, to take special charge of the men working there in compressed air, and therefore felt he had had a somewhat unique opportunity of watching the cases as they occurred and of seeing a considerable number in a comparatively short space of time. There could be no doubt that impurities in the air, from whatever cause, whether from respiration, from explosions or from drains, were all equally deleterious, and caused a great deal of illness among the men; ordinarily when there were no other sources of impurity in the atmosphere in the tunnel, respiratory impurities were alone looked to. It was not, however, his purpose to draw much attention to the details of compressed-air illness, because he had elsewhere dealt with that subject.[1] His object was rather to refer to one particular difficulty he had met with in collecting information on that somewhat important matter. He had had to search among a large number of reports of similar engineering undertakings. They were necessarily generally engineers' reports, and it seemed to him that sometimes engineers were possibly rather absorbed in the engrossing nature of their own occupation, and overlooked, or at any rate under-estimated, the importance and the seriousness of the illnesses occasionally arising from compressed air. In some instances reports of illnesses and fatalities had been Dr. Snell.

[1] "Compressed-Air Illness, or so-called Caisson Disease," London, H. K. Lewis, 1896.

Dr. Snell. published anonymously, apart from the general engineering reports, and the consequence was that, looking at those reports at the present day and studying the records of the illnesses, it was impossible to understand the exact conditions under which the accidents occurred. He was happy to be able to say that the reports to which he was referring were not British. There were also other instances where he had been perfectly certain that serious cases of illness had arisen, and even deaths occurred, without any records of those terrible accidents having been made. Apart from the personal difficulties which he had met with in collecting information of that kind, he wished to submit that publicity in matters of that description was of very great importance, not only to the working men employed, but, and perhaps primarily, to engineers and contractors; for it was largely by publicity that it would be possible to enforce some of the precautionary measures which were now known to be absolutely necessary in order to avoid illness. He somewhat dissented from a statement made by his colleagues, the Authors, that the illnesses in the Blackwall Tunnel were few. They were few compared with other engineering undertakings of a similar magnitude and with similar pressures, but absolutely they were not few. He could himself, when higher pressures were being employed, practically prove the contrary, having had sometimes for weeks to act the part of an owl at night and an early worm in the morning, and he was sure that some of the men would speak very differently as to the statement concerning the infrequency of their illness. In fact, it often happened that many men were so severely affected that they would never come again to the work, so that new hands were being continually employed. He had notes of over 200 cases of illness from compressed air in the Blackwall Tunnel, and he was sure that a certain number had escaped his observation. Fortunately a large number of those cases could not be described as serious. Some of them indeed were trivial, but on the other hand a large number were cases of strong robust men writhing with apparently excruciating pains and suspended from work for weeks and months together. It was therefore hardly accurate to say that such cases were few and trivial. No deaths from compressed air had occurred at the Blackwall Tunnel, and in that respect the staff were exceptionally fortunate, since a considerable number of deaths had previously been recorded where lower pressures had been employed. He thought the exemption in that respect might be traced partly to the advantage of the beneficent auspices of the County Council on the one hand, and on the other to the contractors

Dr. Snell.

who frequently put themselves to considerable inconvenience and expense in order to assist in lessening the causes of illness. It would not be prudent to anticipate that in future operations of that nature there would always be the same happy collocation of generous and humane employers. He thought it was certain, with the experience gained in the Blackwall Tunnel, that precautionary measures against illness must be employed in future operations, not only as rigidly but probably more rigidly than had been adopted, in order that a similar clear sheet of fatalities might be shown.

Mr. Fox.

Mr. Francis Fox, of Westminster, had visited both the Hudson River Tunnel and also the bridge over the Mississippi at St. Louis, in which compressed air was used at, he believed, the greatest depth it had ever been employed, viz., 113 feet 6 inches, and he could state that the experience derived from those two great works had borne fruit in the magnificent work described in the Paper. If the emergency air-lock had been employed at the Hudson River Tunnel those men would never have been drowned at the time of the blow-out in one of the headings. There was only one air-lock, and its door was closed against the men, with the consequence that twenty-three of them were drowned. It was stated in the Paper that the maximum quantity pumped was 2,500 gallons per minute, but after pumping for some time that quantity was materially reduced. To engineers engaged in extensive pumping operations information on that point would be of value. With regard to keeping the caissons vertical, he ventured to think it was a mistake to construct them with a batter; he thought the sides should be vertical. In a large caisson which he had sunk some years ago, 43 feet in diameter, it had been thought that the skin friction would be relieved by reducing the diameter in steps, and the greatest difficulty had been occasioned in keeping the caisson in its place and upright. At one time the caisson was 5 feet out of the level, but it was righted by the application of a water-jet on the high side, to soften the material, and it required no loading. Therefore, in some caissons now being sunk, he had had them provided with water-jets through the skin and connected with a series of valves, so that any portion of the outside skin of the caisson could be lubricated and the skin friction overcome when required. In regard to the shield, a very modest reference had been made to it in the Paper, but he thought the greatest possible credit was due to the gentleman, whoever he was, who had hit upon the idea by which the shield, which weighed 220 tons or 230 tons, was lowered from the bank at the top of the

Mr. Fox. shaft to the bottom. He believed in the minds of many persons that it was a puzzle how to get it there, because to erect tackle to lower 220 tons to the bottom was no light matter. Someone, however—he thought it should be known who it was—had recommended that the shaft should be allowed to fill with water, and that the shield should be launched as a boat, and then, by pumping the water out of the shaft, the boat might be easily lowered into its place. It had been adjusted with the greatest possible ease at the bottom without any trouble. He thought it a most ingenious idea well worthy of being copied. With regard to the question of the illness of the men, he might mention that at the St. Louis Bridge, on the first pier sunk, twelve men had been lost, while on the second pier, which was sunk under exactly similar conditions, with certain precautions, only one man had been lost. He thought the thanks, not only of the Institution, but of the engineering profession throughout the world, were due for the careful investigations instituted by the Engineer of the London County Council in regard to the occurrence of illness among the men working in compressed air.

Mr. Binnie. Mr. Alexander R. Binnie said that after the kind words that had been showered upon him from so many quarters, he rose with some diffidence to make a few observations on the subject. The London County Council had in every way been fortunate in the great work that they had undertaken, fortunate in their original designs, in being aided by their many professional friends, fortunate in the precautions which they adopted to prevent the possibility of accident, most fortunate in obtaining a good contractor, and a good agent and engineer for that contractor. He wished to be allowed to contribute his meed of praise, and to say openly that without the very able assistance which Mr. Moir had rendered, he thought the work, which had been brought to a successful conclusion, could never have been accomplished. With regard to the work itself, he wished, if possible, to call attention to the lessons that might be derived in future from the experience acquired. What had been contributed to the general sum of knowledge on the subject? He thought it might be said in broad terms that the two and a half years' work at the Blackwall Tunnel had demonstrated that it was quite possible to work in an air-pressure 35 lbs. pressure above the atmosphere with comparative immunity to the men. That was a great step, but it was not all that he anticipated. Dr. Snell's remarks were most valuable, and all members of the engineering profession would do well to obtain the volume which he had published on the physical and physio-

logical effects of working in compressed air. First, Dr. Snell had demonstrated beyond the possibility of contradiction that health in compressed air was largely due to the amount of compressed air which was pumped down; in other words, what might be called super-ventilation was absolutely necessary. But he looked further than that. From what he had seen and heard, he went a little beyond Dr. Snell, and thought that if the work under compressed air in the future was to be perfect something more must be done to make the air pumped down as pure as possible. Any one who had visited the works at the Blackwall Tunnel would have noticed that the air was highly saturated at all times with moisture—so highly saturated that the slightest fall in pressure instantly caused a dense fog. He thought that much of that moisture might be removed. The air which was pumped down had passed through the valves of engines, and it was perceptible certainly to him, if not to others, that it was very highly charged with various fatty and oily matters. He thought that by proper precautions, without any great expense, all those impurities of a grosser kind might be removed from the air, and by the adoption of other means, which it was not necessary for him to indicate, he thought compressed air might be obtained of a considerable degree of purity, certainly as pure as, if not purer than, the air which they were then breathing. Proper precautions should also be taken, such as had been indicated by Dr. Snell, that no man should be allowed to go into the compressed air who was not perfectly healthy. He did not mean healthy in the ordinary sense of the word, but, as Dr. Snell had said at an early period of his association with him, what a life-insurance company would call a first-class life. But even then there were some constitutions that could, and some that could not, stand compressed air, and the sooner those who could not stand it were eliminated the better. That meant constant daily supervision of the staff. But in the end he thought it would be found that that would pay, even on the very lowest grounds of economic statistics, and that they might in the future be able to carry on work of that description not only with engineering success, but without any of those ills to which human flesh was heir in all its undertakings. Looking at the model of the shield used by Brunel which was before them, and thinking of the difficulties which its constructor encountered with that somewhat complicated, though highly ingenious, shield in passing under the Thames, and then turning to the model of the shield used at the Blackwall Tunnel, it would be seen that a great step had been made in the fifty-five years that had elapsed between the two Mr. Binnie.

Mr. Binnie. undertakings. In the one case to a large extent brute force had been used; in the other there had been the adaptation of more recent appliances, and, as he had pointed out on a previous occasion when speaking on the subject, they were largely indebted to the distinguished Admiral, Lord Cochrane, for having suggested the method of working. His patent was taken out while Brunel's shield was being worked, but it was only brought into full operation for that particular purpose when the other shield was being pushed forward. It was unnecessary that he should add anything further than to say how much he was personally indebted to the Authors of the Paper, the two resident engineers, who, during the six years they had been engaged at Blackwall, had displayed an ability, a zeal, and a perseverance, often under circumstances of difficulty and danger; and he felt sure that to Messrs. Hay and Fitzmaurice their united thanks were due for giving them so clear and vivid an account of the largest and most difficult work which had been carried out in London in recent years.

Mr. Imray. Mr. JOHN IMRAY thought that before the discussion terminated, it was the duty of the members to give some credit to his lamented friend, Mr. J. H. Greathead, for the efforts he had made in bringing that branch of engineering work to perfection. It was now nearly sixty years since, at the office of Messrs. Maudslay Sons and Field, Mr. Imray had been set to make the drawings for Sir Isambard Brunel's improved shield. The very shield exhibited on the table had come, he believed, from his pencil. Much, however, had been changed since that time. When the late Mr. Peter Barlow designed the Tower Subway, Mr. Greathead was his pupil, and Mr. Imray was in constant communication with both during that period, and he might, without vanity, take credit to himself for having first suggested the idea of pumping liquid cement into the space between the shield and the tube. Not only had that been carried out very fully by Mr. Greathead, but the idea of the shield, constructed as it now was with a cutting front, an air-lock, and so on, was also Mr. Greathead's invention. It would therefore be hard if the discussion were allowed to terminate without reference being made to the immense amount of good that Mr. Greathead had achieved in that direction.

Mr. Deacon. Mr. G. F. DEACON said that the experience gained in connection with the Blackwall Tunnel was, in respect of driving, very similar to that acquired on a smaller scale in the aqueduct tunnel under the Mersey. In dealing with what might be called exceedingly bad ground for ordinary work there was no difficulty whatever, provided the ground was fairly uniform. The difficulty arose

Mr. Deacon.

when the materials differed in resistance to the passage of air or water. He had found under the Mersey, as had been found at Blackwall, that the pressure was never equal to the hydrostatic pressure, because there was a balloon, more or less perfect, of air held in the interstices of the gravel and sand just outside the shield which displaced a large portion of the water-pressure. There was always a trickle of water into the tunnel at the bottom of the shield, and thus in fairly uniform ground a balance was maintained between the friction of the water passing through the gravel and the resistance of the air passing upwards. When, as in the Blackwall Tunnel, the diameter was great, or when in a single face the permeability of the materials differed largely, this balance was very difficult to maintain, and it was in such cases that the immense advantage of working in compartments, as in the Blackwall Tunnel, was felt. He agreed with the remarks of Mr. Francis Fox as to tapering the caissons. His own experience had been that parallel caissons were more likely to remain vertical than any other form, and he believed that lubrication was, as had been pointed out, the secret of success. The tapering of the caisson involved some displacement of the material surrounding the caisson as it descended; and directly that displacement occurred, there was a slip, or tendency to a slip, increasing—but unequally—the pressure on the shield, and holding it tighter than would be the case if that slip had never occurred. There was no possibility of avoiding such slips if the upper part of the caisson was smaller than the lower part. He had never had an opportunity of trying the injection of water as a lubricator from inside the shaft, as described by Mr. Francis Fox; but it appeared to him perfectly rational, and in all cases it would probably prove a much better expedient than tapering. In one of the shafts, only 10 feet in diameter, at the Vyrnwy Aqueduct Tunnel the contractor had at one time about 1,000 tons weight of cast-iron tunnel segments in use as kentledge; and it was only with this, in addition to the weight of the caisson, that movement had been obtained. These shafts were parallel, and the caissons sank vertically. He would only add that he had visited the Blackwall Tunnel on several occasions with Mr. Binnie, and anything more admirable than the manner in which the whole work was conducted it was impossible to conceive.

Sir Benjamin Baker.

Sir BENJAMIN BAKER, K.C.M.G., Past-President, thought there was little to be said on the subject of the Paper, except that all agreed that they were in the presence of a work which, of its class, could be compared with nothing, unless the period of

Sir Benjamin Baker. the Thames Tunnel was recalled. He spoke both of the boldness of conception and the perseverance and ability with which the work had been carried out. All intermediate works were really insignificant in comparison. He had visited all the subaqueous tunnels of importance except the Thames Tunnel. The Hudson Tunnel and others he had been intimately associated with as Consulting Engineer, and he had also visited Sarnia; he had no hesitation in saying, without any reservation whatever, that there was nothing in the world that could be compared with the work that had been successfully accomplished at Blackwall. In looking back some years to the inception of the work, it would be remembered that their highly esteemed and by no means forgotten Past-President, Sir Joseph Bazalgette, was its proposer. He well remembered when Sir Joseph Bazalgette first summoned Sir Frederick Bramwell and himself in conference, and when they were bent over the chart of the river for many days considering the subject, coming unanimously to the decision that the work was practicable, but that it could only be carried out successfully on one system—the combination of the Brunel shield of 1818 and the Cochrane air-pressure of 1830. They had prepared various plans at that time. The Metropolitan Board of Works said that they must have three tunnels—two for roads and one for footway, and the designs had been prepared accordingly for shields and compressed air. The Act of Parliament was obtained; then changes had occurred, and finally it was decided to adopt a single cast-iron tunnel for roadway and footway, and, strange to say, in coming to that decision they simply reverted to Brunel's original patent of 1818. If there was a copy left at the Patent Office, anyone could see that the tunnel which Brunel originally proposed was a cast-iron tunnel built of segments and constructed by means of a shield without compressed air. Cochrane's plan was the use of compressed air without a shield. At the Hudson Tunnel, Haskin re-invented Cochrane's method, and he had carried out the work at the rate of about 30 inches per day. Brunel had carried on his work with a shield and without compressed air at the average rate of 15 inches per day for an entire year, but his tunnel was double the size of the other. The cost per cubic yard of the Thames Tunnel excavation, including brickwork, when all was going well, was about £6 per cubic yard, and at the Hudson about £4; but these prices were liable to be increased tenfold from accidents. The combination of the two systems—shield and compressed air—was undoubtedly the right thing; and it was worthy of record that within a month or two after the Act had

Sir Benjamin Baker.

been obtained for constructing the Blackwall Tunnel on that plan, it became necessary to use it for the first time anywhere in the world on a short length of the City and South London Railway in Swan Lane, where gravel and water were unexpectedly met with. There could be no question whatever, as regards the Blackwall Tunnel, that nothing of the sort had been done before, and credit was due to the engineers and contractors for having undertaken an absolutely original work without guidance from anybody else. He would remind Mr. Imray that, in the case of the City and South London Railway, when gravel was reached, Mr. Greathead did not resort to his own patented methods of subaqueous tunnelling, but the system followed was to make an old-fashioned timbered heading in advance and push forward the shield into it. That was only a 10-foot 6-inch tunnel, and the system was entirely different from the system followed at the Blackwall 27-foot tunnel, where a shield of original design, adapted to tunnelling through loose gravel with the river overhead, was employed. The method followed by Mr. Greathead on the City and South London Railway, and by the Canadians at Sarnia and other engineers elsewhere, was absolutely inapplicable at Blackwall. It was no guidance whatever to Mr. Binnie, Mr. Hay, or Mr. Fitzmaurice, or, above all, to Sir Weetman Pearson and Mr. Moir. It would be unfair, therefore, to detract in any way from the credit due to those gentlemen for their pluck, their bold assumption of responsibility, and consequent success, with which they had carried out the work. In regard to the question of compressed air, he thought Dr. Snell had not had the opportunity, which most doctors under similar circumstances had had, of making a good many post-mortem examinations. There had not been a single death under compressed air in the Blackwall Tunnel, and there had, therefore, been no such medical information gained as there would have been if there had been a less wealthy employer than the London County Council, and a less disinterested contractor than Sir Weetman Pearson. The knowledge that they had hitherto received was chiefly in regard to cases where men were working under high pressure, with insufficient supplies of air, and when economy was exercised in every possible way. In the present case, however, there was the curious and anomalous result that in one of the avowedly most risky works ever undertaken, instead of having about twenty lives lost (as would probably have been the case in building a ship, or anything else of the same value, or quarrying for coal) there had been hardly any deaths, thus upsetting all theory, and apparently demonstrating that working in compressed air was the most

Sir Benjamin Baker. healthy employment that a workman could be engaged in. He quite agreed that it would be well for every engineer to consult Dr. Snell's work, which should also be supplemented by the results of post-mortem examinations elsewhere. He had spoken with many medical men on the subject, and had been in the Hudson Tunnel when the atmosphere was in a very queer condition. He did not know whether his would be a "first-class" life in Dr. Snell's opinion, but he had never suffered any inconvenience even when there were 3 or 4 parts in 1,000 of carbonic acid and 3 atmospheres pressure.

Mr. Bull. Mr. WILLIAM BULL remarked that there had been a great many difficulties in connection with the undertaking other than those of an engineering character. It was a long time before Parliament could be persuaded in the first instance to take the matter in hand, and there had been many opponents to the scheme in various ways. As had been remarked by other speakers, there had at first been a proposal that the tunnel should be in three parts, two for vehicles, and one for passengers; and it had been proposed to make the passenger tunnel first. But there were persons on both sides of the river who, taking a deep interest in the subject of trans-communication, believed that if a passenger tunnel were made first it would be an entire failure, and the result would be that no vehicular tunnel would afterwards be made. There was a great deal of opposition from other quarters. Professional opinions had been given to the effect that a tunnel of that size could not possibly be made in such a soil, while others stated that if the tunnel were made no one would ever use it. It was further alleged that the expense would be so great that it would not be worth making at all. The members would therefore understand that many difficulties were encountered before the construction of the tunnel was begun. As Chairman of the Committee that had to superintend the work, he should like to add his meed of praise for the admirable way in which it had been carried on by the professional advisers and contractors. From the first the London County Council had seen that in a difficult undertaking of that nature it would be best to give the freest hand to those professional advisers, and he thought it would be admitted that a free hand had been given them, to the satisfaction not only of the Council, but, he hoped, also of the contractors. He could only assure the Institution how proud the Bridges Committee felt in having taken the small part which had devolved upon them in connection with such a splendid work. He thought the London County Council had been entirely weaned from their idea of ferries and high-level bridges, and were now in

favour of tunnelling. The success of the Blackwall Tunnel had been such that there would be no difficulty in persuading their colleagues in the London County Council in future that where trans-communications were wanted across the river they should be in the form of such a tunnel as had just been constructed. At Greenwich it was proposed to make a small foot-tunnel, which had been designed by Mr. Binnie, at what was considered a very moderate price, and later on, when the usefulness of the Blackwall Tunnel had been proved, as it no doubt would be from every point of view, they might start with an even more ambitious tunnel at Rotherhithe. Then, and not till then, the means of trans-communication across the river east of London Bridge would be complete. Mr. Bull.

Mr. WALTER HUNTER was glad to hear that the London County Council had been converted to tunnels by the success of the work described in the Paper. Owing to the position that they occupied, Messrs. Osborn and Bullivant were largely responsible for pressing the work upon the consideration of the Council, and he warmly congratulated the professional advisers, especially Mr. Binnie and his engineers, as well as Sir Weetman Pearson and Mr. Moir, upon the great success that had attended the work. They had a very difficult task to get the matter through the Council at all. It was often easier to engineer materials than it was to engineer men; and they had had to engineer men and to make them see that the wants of East London had been greatly neglected. He believed the County Council were earnestly desirous to do justice, but they did not know the facts of the case. Most of the members lived in the West, and could appreciate any work which contributed to their own convenience. When they first started, the Council was somewhat against them, but they demonstrated clearly the advantages which the tunnel would possess; and it was, no doubt, a great satisfaction to him to find that it had been carried out, after being told that it would cost millions, within the estimate which Mr. Binnie had given. At the time the matter was taken up, Sir Benjamin Baker went to New York, examined the Hudson River Tunnel and presented a favourable report upon his return. Mr. Osborn and Mr. Hunter then said to him, "We should like you to carry out the work"; but he said he did not care to do it, his real reason, no doubt, being that he did not care to have 137 masters. Mr. Binnie was then approached, but he said, "No; this has been Sir Joseph Bazalgette's work mainly, for which his son Mr. Edward Bazalgette is somewhat responsible, and in the first instance I think it ought to be offered to him." He thought Mr. Hunter.

Mr. Hunter. that for the chief engineer of the London County Council to offer to give way to a subordinate in that manner (although the subordinate would not undertake the work), redounded greatly to his credit, and ought to be generally known.

Sir Frederick Bramwell. Sir FREDERICK BRAMWELL, Bart, Past-President, did not know that he had anything to add, except to pose as one of those, who, with the eldest of the Brunels, was in the shield in the old Thames Tunnel, and saw the work carried on there. He had seen the Wapping shaft sunk, which, as was well known, was a parallel brick shaft, rendered outside and lubricated. The sinking of that shaft had been carried out without difficulty. He was glad to hear what had fallen from members of the County Council as to the possibility of the extension of the tunnelling system; but he hoped that if they did extend it, they would take into serious account whether, having regard to the fact that in these days hydraulic lifts were as absolutely safe and to be depended upon as any known piece of mechanism, it might not be well to reconsider the plan of Sir Joseph Bazalgette, which the Committee of the House of Commons would not pass, to do away with long approaches, and to have hydraulic lifts for vehicular traffic as well as for foot passengers.

Mr. Fitzmaurice. Mr. FITZMAURICE, in reply, said that one of the minor difficulties was that referred to in connection with the puddled clay used to back up the cut-and-cover in the first instance and to keep the water out. It did keep the water out, but it did not keep the tunnel up very satisfactorily, as the arch yielded when the filling was put on, and it was unsatisfactory to see the crown of the brickwork in the tunnel slightly opening out. The difficulty had been overcome at Mr. Binnie's suggestion by driving piles outside. Afterwards asphalt was almost entirely relied on for watertightness. At the same time, he thought that in the open approach work the clay would probably have been as good as asphalt at the back of the walls where it had not to take up pressure. One of the features of the tunnel was the great extent to which asphalt had been used. It was of British manufacture, and was applied in three layers. In one or two cases, owing to expansion and contraction, it had cracked, and the water had come through, but altogether it had proved very satisfactory. The accident which had happened to the shield when the edge was buckled up certainly showed the importance of examining the ground in front of the shield, to see that there was no rock of any kind which might cause further damage. A great deal of care was necessary in driving the shield so as to avoid the ground coming down on the top,

particularly in the ballast. There was hardly any subsidence of the ground in clay, but in ballast, unless great care was taken, it was very considerable. The Brunel shield and the Blackwall shield were almost exactly of the same weight. Looking at the models of the two, he thought it was obvious that very great progress had been made; the Brunel shield was in several pieces, and it was a marvel that it ever got across the Thames. He thought Brunel's tunnel was one of the most remarkable things ever accomplished. With regard to the Blackwall Tunnel, the shutters used in the shield were amongst the principal things which had helped them to get under the river. They were due to a suggestion of Sir Benjamin Baker. No one who was not actually present in the shield could realize the feeling of safety given by the shutters, as they completely closed the face when necessary, there being only ½ inch space between them. Without them he thought it would have been almost impossible to have got under that part of the river where all the excavation was in gravel. In the contract drawings an air-tight floor was shown in the caissons below the level of the tunnel. At the request of the contractors that had been altered, and the air-tight floor above the tunnel, which would have been necessary in any case, was alone used. That left the lower part of the caisson without any floor across it. He thought that where compressed air was to be used from the beginning of the sinking, it was much better to have an air-tight floor at the bottom. It bound the whole caisson better together, and though it might be slower in sinking, it made more satisfactory work. Provision was made for lubricating the caisson by water-pipes through the skins, but they were never necessary. One of the caissons did get 14½ inches out of level, but that was the worst case. He was glad the London County Council had taken from the beginning such interest in the tunnel, and that they were going to make other tunnels under the Thames. He knew of one town where the river, which ran through the middle of it, was completely arched over. He supposed that a similar but inverted state of things would never be arrived at in the case of the Thames; it might however, come some day—a tunnel under the river from end to end. He had hoped that he might have been able to say, as he had been saying for five years, that the Blackwall Tunnel shield was the largest ever used, but he had just received a blow in a letter from an engineer in Boston, saying, "We are now starting a shield 30 feet in diameter." It was only for a very short length, still it was larger than the Blackwall Tunnel shield. Mr. Fitzmaurice.

Mr. Moir. Mr. MOIR said in reply to the question as to who had suggested the shield should be lowered down the shaft in the way described, that the first suggestion was due to Sir William Arrol.

Mr. Preece. Mr. W. H. PREECE, C.B., Vice-President, thought the Institution might congratulate itself on having brought the session to a conclusion with an extremely valuable and interesting Paper, and with a discussion perhaps of as great interest and as high in tone as any discussion that had taken place in the Institution during recent years. He was proud to think that an engineering work of that grandeur could be carried out with such marvellous results in regard to its effects on human life. It was something to say that so much money and so much time had been spent in driving a roadway beneath the Thames without the loss of a single life. That he thought must redound as much to the credit of the County Council as it did to the credit of the body of engineers represented in the Institution.

Correspondence.

Mr. Elwin. Mr. C. ELWIN remarked that as long ago as 1881 part of the engineering staff of the Metropolitan Board of Works had been engaged, under the late Sir J. W. Bazalgette, in preparing designs and estimates for subways crossing under the Thames at various points below London Bridge; and during the parliamentary session of 1884, the Board had promoted a Bill for the construction of a subway under the river near Nightingale Lane, Wapping. It was to consist of two openings, one for vehicular and one for pedestrian traffic, with inclined approaches on both sides of the river, together with hydraulic lifts on the north side. The Committee of the House of Commons had declined to pass the Bill, and intimated that in their opinion, in order to provide suitable additional means of crossing the river below London Bridge, there should be a low-level opening bridge near the Tower, and a subway at Shadwell. The Tower Bridge had since been constructed by the City Corporation. A scheme for a subway between Shadwell and Rotherhithe had been prepared before the Nightingale Lane subway scheme had been brought forward, but the estimated cost was very large, and the Board were not disposed to proceed with it. In 1886 the Blackwall Tunnel scheme, at a smaller estimated cost than that of the Shadwell Tunnel, had been prepared, and in 1887 parliamentary powers were obtained for its construction. It was not realized in the first instance how

Mr. Elwin.

difficult was the task proposed, but as the various borings proceeded and revealed the character of the strata through which the subway would have to be constructed, it became more and more evident that the work would be one of no ordinary kind. In addition to the method of construction by tunnelling, various other methods, more or less practicable, had been considered. Construction by means of comparatively short lengths of caissons or cofferdams, &c., sunk or driven into the river-bed, although suggested, was soon found to be impracticable on account of the river-traffic and strong tide. A scheme had also been prepared for constructing the subway in a long iron or steel tube which was to be floated over a trench previously dredged in the river-bed and lowered into position. Eventually it became apparent that, in spite of the unfavourable conditions for such work, tunnelling with a shield aided by compressed air was the only practical method of constructing the subway. Brick construction, to be built up inside the back part of the shield, was in the first instance proposed, but subsequently it had been decided to adopt cast-iron segments. These were so proportioned as to make a ring sufficiently strong in itself to resist all the pressures which could be brought upon the subway without any assistance from brick or concrete lining, which obviously could not be added till after the cast-iron rings were completed and had been liable to the full pressures. The cut-and-cover portions of the subway were designed so as to allow buildings to be erected over them. Sufficient land had been purchased by the County Council to enable a second tunnel to be constructed in close proximity to the present one. The question of the need for mechanical ventilation for the tunnel had always been felt a difficult one to decide, and even now it might be an open question if during certain weather it would not be necessary to have such mechanical ventilation. Probably on many days in the year, the wind would blow along one or the other of the open approaches, and on these occasions there might be too much ventilation. As stated by the Authors, means of ventilation had to some extent been provided and could be completed if mechanical ventilation should be found necessary in the future.

The question of the cost of lifts as compared with that of inclined approaches in connection with the Blackwall Tunnel had been discussed at some length soon after the County Council succeeded the Metropolitan Board, but, taking into consideration first cost and working expenses, it did not appear, at any rate in the case of the Blackwall Tunnel scheme, that any saving would be effected by the adoption of lifts, if these were to be of sufficient

Mr. Elwin. capacity to accommodate an amount of traffic in itself large enough to justify the necessary expenditure on the portion of the tunnel which must, in any case, have been constructed between the sites of the lift-shafts on the opposite sides of the river. It might be that for approaches to tunnels where the value of the properties required to be purchased was much greater than at Blackwall, the more economical course would be to adopt lifts in preference to inclined approaches, but this point could only be decided according to the particular circumstances of each case.

Mr. Tapscott. Mr. R. LETHBRIDGE TAPSCOTT observed that, having regard to the difficulties encountered in constructing the tunnel under the Thames and the simple arrangement of depositing clay on the bed of the river from hopper barges, it was gratifying to hear that success had been attained, and that no difficulty had been experienced in maintaining the line of the tunnel through the bad ground. It appeared, therefore, that no serious break occurred in the continuity of the strata beneath the tunnel such as to require any special work in making foundations by heavy timbering. The shield must have been of considerable weight to maintain itself at the same level, as it was driven forward by the hydraulic jacks, and would probably have had a tendency to dip, thus necessitating guiding to some extent.

ANNUAL GENERAL MEETING.

27 April, 1897.

JOHN WOLFE BARRY, C.B., LL.D., F.R.S., President, in the Chair.

The Notice convening the Meeting was taken as read, as well as the Minutes of the Annual General Meeting of the 2nd June, 1896, which the President was authorized to sign.

The Report of the Council upon the Proceedings of the Institution during the Session 1896–97 was read, with an abstract of the Statement of Accounts.

After consideration it was resolved,—That the Report of the Council be received and approved, and that it be printed in the Minutes of Proceedings.

The Scrutineers reported the election of:—

President.

JOHN WOLFE BARRY, C.B., LL.D., F.R.S.

Vice-Presidents.

William Henry Preece, C.B., F.R.S.
Sir Douglas Fox.
James Mansergh.
Sir William Anderson, K.C.B., D.C.L., F.R.S.

Other Members of Council.

Horace Bell.
Alexander Richardson Binnie.
Thomas Forster Brown.
Henry Deane, M.A.
William Robert Galbraith.
George Graham.
J. C. Hawkshaw, M.A.
Charles Hawksley.
George Henry Hill.
John Hopkinson, Jun., M.A., D.Sc., F.R.S.
James Charles Inglis.
Alexander Blackie William Kennedy, LL.D., F.R.S.
John Kennedy.
George Fosbery Lyster.
William Matthews.
Sir Guilford L. Molesworth, K.C.I.E.
Captain Sir Andrew Noble, K.C.B., F.R.S., late R.A.
Bindon Blood Stoney, LL.D., F.R.S.
Francis William Webb.
Sir William Henry White, K.C.B., LL.D., F.R.S.
Sir Edward Leader Williams.

Resolved,—That the thanks of the meeting be given to the Scrutineers, and that the Ballot-Papers be destroyed.

Mr. George Chatterton responded on behalf of the Scrutineers.

Resolved,—That Messrs. Arthur Cameron Hurtzig and John George Griffiths be appointed Auditors for the ensuing year; and that the thanks of the Institution be tendered to them for the time and trouble bestowed by them in auditing the Accounts for the past financial year.

Resolved,—That the thanks of the Institution be tendered to the Vice-Presidents and other Members of Council for the assistance they had rendered in promoting its objects.

Mr. Preece replied on his own behalf and on that of his colleagues.

Resolved,—That the members present at this meeting desire, on behalf of themselves and others, to place on record their high appreciation of the services rendered to the Institution by Mr. J. Wolfe Barry, President, during his year of office.

Mr. Wolfe Barry acknowledged the Resolution.

Resolved,—That the hearty thanks of the Institution be given to the Secretary and the Staff.

Dr. Tudsbery, Secretary, replied.

The Meeting then ended.

REPORT OF THE COUNCIL, Session 1896–97.

The presentation of this Report upon the state of the Institution forms, according to the By-laws, the conclusion of the duties with which the Council were charged upon their election at the end of the last Session.

Dealing first with important changes made during the Session, which affect the Institution as a body, the alterations of the By-laws enacted at the Special General Meeting held on the 30th March[1] must be noticed. The principal feature of these changes is the introduction of a test, by examination, of the general and scientific knowledge of candidates for election into the class of Associate Members. Up to the present time Associate Members have been passed by the Council for Ballot after an investigation into their training and into their subsequent career, and the Council believe that, as a rule, satisfactory results have been obtained. But in these days, when the application of science to engineering is being so very largely developed, it becomes more and more necessary to ensure that those who are admitted into the Associate Member class should not only fulfil the conditions hitherto demanded, but should, in addition, offer satisfactory evidence of their acquaintance with those branches of science which form the basis of engineering. The Council therefore felt it their duty to institute an exhaustive inquiry, extending over a period of three months, which inquiry resulted in their unanimously recommending the adoption of a system of examinations. The unanimity with which the General Meeting adopted the recommendation, and the approbation with which it has generally been received among the members have afforded gratifying evidence to the Council of the support accorded to their views of that which they conceived to be for the best interest of the Institution. The detailed arrangements for giving effect to the new rules are under consideration, and will it is expected be settled shortly. Another change adopted by the same Special General Meeting has been to render it competent for the Council to deal with any case of disgraceful conduct in any professional respect on the part of a member, without the necessity for the matter being first the subject

[1] *Ante*, p. 1.

of a memorial from twenty members, and of other cumbrous and invidious modes of procedure. Some amendments were also introduced into the articles affecting finance, and the life-composition fee was, after taking advice of an actuary, raised to a uniform sum of sixty guineas. Advantage was taken of the revision of the By-laws to define more concisely the several classes constituting and attached to the Institution, and in particular to give official recognition to the term "Associate Member" in accordance with the principles laid down when the class was formed in 1878.

A copy of the By-laws thus amended and revised accompanies this Report, and will be placed in the hands of all those belonging to the Institution.

Another matter engaging the attention of the Council during their year of office, has been the necessity for the exercise of care and vigilance lest the Institution should suffer in prestige by any implied association with undertakings that form no part of its objects, or from the adoption by other bodies of names or titles calculated to mislead or confuse the public in regard to the individuality of this Institution. In the case of a proposal to incorporate a body under the title of "The Institution of Civil and Mining Engineers," the Council took steps to resist to the utmost that which they deemed would have a prejudicial effect upon the Institution, with the result that the body in question adopted a title for their undertaking which was unobjectionable.

A more agreeable task is to record the warm regard and loyalty towards the Institution evinced among the members in various parts of the country visited by representatives of the Council during the past Session. Many of the members who are so situated as to be unable to attend the weekly meetings in London, are active in lending countenance and support to the local Associations of Students, which have thus become of no little value in promoting union among the profession in the localities referred to. The Council, with the view of still further promoting this union, propose to hold a general conference of the Institution in London on the 25th, 26th and 27th May next. It is hoped that this opportunity for men practising various branches of engineering in all parts of the kingdom, to meet in the Metropolis for the interchange of professional views, may satisfy a need that has been felt in an increasing degree with the expansion of the Institution.

The Council has, in accordance with the provisions of the By-laws, fixed the number of its successors at 26, including the President and Vice-Presidents, but exclusive of Past-Presidents.

The balloting list has therefore to contain 28 names—being two more than the number to be elected. At the unanimous request of the Council, Mr. J. Wolfe Barry consented to be again nominated as President, and the names of the Vice-Presidents were also placed in the balloting-list without change. The death of Mr. Greathead, and a desire expressed by Mr. Shelford that his name should not be put forward this year, accounts for the disappearance of the names of two members of the Council last elected, and in accordance with the By-laws 7 new names have been placed on the balloting list.

The Secretaryship.

Since the last Annual General Meeting, Mr. James Forrest has retired from the post of Secretary, which he has so long and ably filled, and has been appointed the Honorary Secretary. In recording this change, the Council may perhaps be permitted to adcpt the following extract from the President's Inaugural Address:—

"Mr. Forrest has been connected with the Institution for fifty-four years, and has been Assistant Secretary or Secretary for forty years. He has known all the Presidents with the exception only of Telford, and has seen almost the whole of the remarkable rise of the Institution in numbers, wealth, and position. . . . When he became Assistant Secretary in 1856, the Institution was considerably in debt, although the publication of the Proceedings was in arrear. Now we publish four expensive volumes yearly, give copies to many kindred bodies, and discharge all our liabilities. . . . Very much of this management has been due to the sagacity and devotion of Mr. Forrest. It may truly be said of him that he has not only watched over the interests of the Institution with the greatest assiduity and with complete success, but that his office has been to him a labour of love. Certainly no man ever devoted himself more thoroughly heart and soul to his work than has Mr. Forrest from first to last during his long tenure of office."

Mr. Forrest has been succeeded in the Secretaryship by Dr. J. H. T. Tudsbery, who acted for some years as Assistant Secretary; whilst Dr. Pole on retiring from the post of Honorary Secretary, has been elected an Honorary Member of the Institution.

The Roll.

The changes which have taken place in the Roll during the year ending the 31st March, 1897, are stated in the accompanying Table. The elections numbered 2 Honorary Members, 37 Members, 279 Associate Members, and 8 Associates; in addition to which 1 Member and 5 Associate Members were reinstated—a total of 332.

By death, resignation, and erasure, 158 names disappeared from the register, the net increase being thus 174. The roll numbered on 31st March 6,204, exclusive of Students, as against 6,030 on the corresponding date of last year.

—	April 1, 1895, to March 31, 1896.					April 1, 1896, to March 31, 1897.				
	Honorary Members.	Members.	Associate Members.	Associates.	Totals.	Honorary Members.	Members.	Associate Members.	Associates.	Totals.
Numbers at commencement	17	1,862	3,687	355	5,921	20	1,884	3,788	338	6,030
Transferred to Members	..	57	55	2		..	71	71	..	
Elections	3	27	244	9	290	2	37	279	8	332
Restored to Register	..	1	6	..		..	1	5	..	
Elected Honorary Member	..	..	1	..		..	1	..	1	
Deaths	..	40	35	17	181	1	38	34	9	158
Resignations	..	10	21	6		..	10	24	3	
Erased	..	13	37	1	109	..	8	27	2	174
Numbers at termination	20	1,884	3,788	338	6,030	21	1,936	3,916	331	6,204

Including Students, the number borne on the books was on the 31st March, 1897, 7,090. The amount of work devolving upon the Secretarial staff in dealing with this number may be partly realised from the fact that the changes of individual addresses recorded in the books during the past year have exceeded 1,600; whilst the number of letters, notices and packets despatched from the Institution during the same period has been not less than 125,000. The Council has, during the Session, considered 390 applications for election, and 99 for transfer—a total of 489 proposals dealt with, exclusive of recommendations for the admission of Students.

Among the deceases recorded are those of Sir William Grove, a most distinguished Honorary Member; of James Henry Greathead, a Member of the Council; of Sir Joseph Prestwich, whose geological researches and writings are familiar to Engineers; and of Major-General George Borlase Tremenheere, whose connection with the Institution began in 1838.

The full list of deceases is as follows:—

Honorary Member.—The Right Hon. Sir William Robert Grove, D.C.L., LL.D., F.R.S.

Members.—John Addy; Philip Barry; John Bennett; Robert William Peregrine Birch; George Bond; Andrew Duncan Cairns; Thomas Carrington; David Cunningham; Elias Dorning; Frederic George Fishenden; Arthur Crouch Folkard; Andrew Foote; Henry Charles Forde; Edward Gotto; John William Gray; James Henry Greathead (*Member of Council*); Robert Lewis Harris; William Haskins; William Wilson Hulse; William Hunt; John William Johnson; Henry George Clopper Ketchum; David Kirkaldy; David Logan; James Atkinson Longridge; James Lyons-Cleminson; Peter John Margary; Thomas Meik; Edward Orpen Moriarty; Carlos Alberto Morsing; John Newton; Drewry Gifford Ottley; John Carter Park; Alexander Prentice; Alfred Rumball; William Scott; George Seymour; and Lionel Barrington Simeon.

Associate Members.—Charles Coles Adley; Thomas Airey; Gustav Valentine Alsing; Alexander Anderson; Edward Nevill Banks; David Leonard Barnes; William Henry Churchward; George Findlater Clements; Edward Hugh Day; Napoleon Edward Drew; Nicholas Dunscombe; John Fenwick; Richard Goodman; Edwin Walter Greenwell; Edward Beresford Hearne, M.E. (*Dubl.*); Herbert Hinds; James Ibbs Lawson; Giulio Cesare Alessandro Melisurgo-Melissenos; Edward Newdigate; Henry Parnham Phillips; David Thomas Rhys Protheroe; James Robinson (*Winchester*); Norman William Roy; Hurrychund Sadasewjee; Jagannath Sadasewjee; Henrique Scheid; Luke George Sgouta; Herbert Wilfrid Skinner; Robert Smith; Athelstan Philip Joseph Stourton; Norman Maughan Taylor; Walter Thomas; John Thornhill; and William Herbert Wheeler, B.A. (*Cantab*).

Associates.—Sir James Browne, *Major-General* R.E., K.C.S.I., C.B.; Thomas Alexis Dash; Alexander Milne Dunlop; Howard John Kennard; William George Margetts; *Sir* Joseph Prestwich, M.A., F.R.S.; George Borlase Tremenheere, *Major-General* R.E. *ret.*; John Salusbury Trevor, *Major-General* R.E. *ret.*, C.S.I.; and Robert Warner.

The following resignations have been accepted:—

Members.—William Boulton; George Richard Clark; Marshal Cresswell; John Daglish; Paul William Dangerfield; John Hingston Fox; Edward Monson George; Fletcher Francis Sheridan Kelsey; John Arthur Dayrell Lloyd; and Thomas Taylor Smith.

Associate Members.—Charles Howard Cotton Bickerton; John Charles Beahan; Francis Charles Buscarlet; William Jeffers Craig; James Gibson Dees; Francis Edward Hamond; John Home Home; Ernest Worthy Horne; Charles Henry Howorth; Fletcher James Ivens; James Percy Knight; William Harrington Lucas; Frederic Thomas Maltby; Frederick Fraser Miller; Robert Edward

Norfor; John Phillips; Cleophas William Ratliff; Thomas Ravenhill; Charles Mitford Smith; Edward Felix Stephens; Edward Augustus Stoney; Theodor Tufvesson; Robert Charles Turner; and George Powell Walker.

Associates.—Francis Bramah Gilbertson; John Francis James Miller, *Colonel Bombay Staff Corps*; and Francis William Robinson.

Admission of Students.

The appended Table shows the changes which have taken place in the Student class during the year under review. The admissions amounted to 193, and 2 were restored to the roll, while of the names which disappeared, it is satisfactory to note that 72 were elected Associate Members and 1 an Associate; in addition to which, it may be assumed from the experience of former years that a further considerable number will be elected into the Institution at a future date. The total on the 31st of March, 1897, was 886, against 877 at the corresponding period of last year.

Compliance with the Council's regulations as to evidence of liberal education on the part of Students is now so general that it may be hoped the rule will become practically absolute, when facilities for obtaining the necessary qualification have been afforded by the Institution itself, as contemplated by the amended By-laws.

Students.

1895–96.				1896–97.			
April 1, 1895 . . .			816	April 1, 1896 . . .			877
Admitted during the year	215			Admitted during the year	193		
Restored to List . .	1			Restored to List . .	2		
		216				195	
Elected Associate Members	58			Elected Associate Members	72		
Elected Associate . .	..			Elected Associate . .	1		
Resigned	17			Resigned	12		
Deceased	3			Deceased	5		
Erased	77			Erased	96		
		155				186	
			61				9
March 31, 1896 . .			877	March 31, 1897 . .			886

Finance.

The Statement of Accounts, vouched for by the Auditors, will be found at p. 112.

The receipts during the year were as follows:—Income, £22,285 8*s*. 10*d*., consisting of subscriptions £18,599 11*s*. 6*d*., dividends £2,124 9*s*. 10*d*., rents £926 10*s*., and miscellaneous

items £634 17*s.* 6*d.*; on capital account to meet expenditure on the new building £15,417 16*s.*, of which £3,910 4*s.* represent admission fees and life compositions, the remainder being derived from the sale of stocks; and from Trust Funds, £466; the total being £38,169 4*s.* 10*d.* The expenditure has been £40,394 8*s.* 9*d.*, under the following heads:—Amount chargeable to Income, £20,082 1*s.* 9*d.*, of which publications absorbed £8,676 5*s.* 1*d.*; to capital, £19,843 15*s.* 1*d.*, incurred principally in connection with the new building; and to Trust Funds £468 11*s.* 11*d.*, of which £60 8*s.* 1*d.* represented an investment of unexpended dividends on behalf of the Palmer Scholarship.

The investments on Institution account, amounting to £49,200 (nominal value), have been purchased at a cost of £50,500 10*s.* 8*d.* In addition to this, various sums, aggregating £17,037 9*s.* 11*d.*, are held in Trust. The £1,400 Debenture Stock forming part of the securities representing the Whitworth legacy has been redeemed by the payment of £1,540; and the 400 shares of £10 each forming the remainder have been redeemed by the payment of £3,000 in cash and the assignment to the Institution of 1,200 shares, of the nominal value of £1 each, in the firm of Sir William Armstrong, Whitworth & Co.

Rates and Taxes.

The liability of the Institution to pay local rates having been repeatedly questioned, notably in the Report of the Council for 1890–91, it has been thought proper to obtain Counsel's opinion upon the question of this liability, as well as upon that relating to Inhabited House Duty, and to Income Tax upon the property. Accordingly, upon a case prepared by Messrs. Hargrove & Co., the opinion of Mr. C. A. Cripps, Q.C., M.P., and of Mr. R. M. Bray was sought. The Council have been advised by those gentlemen (1) that, having regard to recent expressions of opinion by the judges in the House of Lords, the Institution would not have a good chance of success in claiming exemption from local rates; (2) that it is liable for Inhabited House Duty; but (3) that it may justifiably claim exemption from the payment of Income Tax.

The views expressed by Counsel in regard to the last question render it in the opinion of the Council necessary to pursue the matter further, and steps have accordingly been taken to claim exemption from the payment of Income Tax.

Session and Meetings.

The effect of the alteration initiated last year in the period of the Session has been to make the Meetings cover exactly six months, from November to April, both inclusive. During the past Session twenty-two ordinary Meetings were held, at which fifteen Papers were read and discussed, the opening night being, as usual, devoted to the delivery of the President's Address and to the presentation of the medals and premiums.

A Paper on "The Tower Bridge Superstructure," which had been prepared by Mr. G. E. W. Cruttwell as a sequel to his earlier description of the foundations of the same work, fittingly began the Session. It was supplemented by Mr. S. G. Homfray's account of the hydraulic machinery at the bridge. Dr. Percy Frankland's memoir on the "Bacterial Purification of Water" marked the recent progress in this branch of the science of Water-Supply. The employment of improved appliances for handling coal, was discussed in the Papers on "Tipping and Screening Coal" and "Surface Plant at Kirkby Colliery" by Messrs. James Rigg and Thomas Gillott respectively. These Papers, with the discussion and correspondence to which they gave rise, are published in the first part of the Minutes of Proceedings recently issued. Subsequent volumes will contain, in Sect. I., Papers by Mr. E. C. Shankland on "Steel Skeleton Construction in Chicago;" by Professor W. Ripper on "Superheated-Steam Engine Trials;" by Colonel J. Pennycuick on the "Diversion of the Periyar," with a supplementary note by Mr. P. R. Allen on the "Periyar Tunnel;" on "Cold Storage at the London Docks" by Mr. H. F. Donaldson; on the "Main Drainage of London" and the "Purification of the Thames" by Messrs. J. E. Worth and W. Santo Crimp, and Mr. W. J. Dibdin respectively; on the "Mond Gas-producer Plant and its Applications" by Mr. H. A. Humphrey; on "Electric Lifts and Cranes" by Mr. Henry W. Ravenshaw; and on "The Blackwall Tunnel" by Messrs. David Hay and Maurice Fitzmaurice.

The group of Papers selected for publication in Section II. of the Proceedings has been prepared with a view to afford useful examples of works executed, and experimental data, to Engineers in all branches of practice.

The awards for Papers in Sections I. and II. of the Proceedings will be considered collectively in the autumn, after the whole series has been published. The medals and prizes will be presented, as usual, at the opening meeting of the next Session.

In reference to Sect. III. of the Proceedings, it has been decided that in future abstracts of a limited number of important Papers occurring in English publications shall be admitted into this section, with a view to render the series complete and to bring to the notice of members residing abroad useful matters occurring in current scientific literature at home, which otherwise might escape them.

Steam-Engine Efficiency.

The Council have adopted the following Preliminary Report of the Committee appointed a year ago to consider and report upon the definition of a standard or standards of thermal efficiency for steam-engines:—

The Committee beg leave to report that they have now practically come to an agreement on the subject of the reference to them, and that the draft report has been drawn up. It was hoped that this report would have been ready to submit in time for the Annual Meeting, but unforeseen delays have occurred.

The Committee, however, wish now to state that the gist of the conclusions they have come to is as follows:—

(1) That the statement of the economy of a steam-engine in terms of pounds of feed-water per I.HP. per hour is undesirable.

(2) That for all purposes except those of a scientific nature it is desirable to state the economy of a steam-engine in terms of the thermal units required per I.HP. per hour (or per minute), and that if possible the thermal units required per brake HP. should also be given.

(3) That for scientific purposes the thermal units that would be required by a perfect steam-engine working under the same conditions as the actual engine should also be stated.

The proposed method of statement is applicable to engines using superheated steam as well as to those using saturated steam, and the objection to the use of pounds of feed-water, which contain more or less thermal units according to conditions, is obviated, while there is no more practical difficulty in obtaining the thermal units per I.HP. per hour than there is in arriving at the pounds of feed-water.

For scientific purposes the difference in the thermal units per I.HP. required by the perfect steam-engine and by the actual engine shows the loss due to imperfections in the actual engine.

A further great advantage of the proposal is that the ambiguous term "efficiency" is not required.

The Committee will do themselves the honour of submitting their complete Report at an early date.

The "James Forrest" Lecture.

The fifth lecture of the series—"Bacteriology"—was given on the 18th March by Dr. G. Sims Woodhead. The interest evinced by the audience in the lecturer's account of this branch of research, which is so conspicuously commanding the attention of all Engineers

occupied with water-supply and sanitary works, led the Council to arrange for its repetition on the 24th March, when a large company of members and their friends was present. The Council reflect with satisfaction upon the fact that Mr. Forrest has put into their hands the very valuable means of scientific instruction which these lectures afford.

Palmer Scholarship.

The first nomination to the Palmer Scholarship has been made in favour of Mr. Austin Henry Kirby, who will go into residence at Cambridge University in October next in terms of the Founder's bequest.

Students' Meetings.

Nine supplemental Meetings have been held during the Session, the proceedings of the first meeting being opened by an Address from the President. The improvement in the attendance noticed last year has been well maintained, the average having been 50. In addition to the nine Papers read at these meetings, eight have been submitted from the local centres in competition for Miller Prizes. The awards will be made in the autumn and the prizes will be presented at the opening meeting of next Session. In addition to the Miller Prizes, the Council have this year to award the James Prescott Joule Medal. The interest Mr. Forrest takes in the Student class has led him to ask that part of a sum of money—subscribed by past and present Members of Council to present him with a token of their esteem—should be devoted to the provision of a medal to be presented annually to the writer of the best Paper by any Student, and the "James Forrest" Medal will in due course form one of the awards in the gift of the Council.

Six visits to engineering works have been made, the average attendance at which was less than might be expected from the large number of Students resident in London. The Local Associations at Manchester, Glasgow, Birmingham, Newcastle-on-Tyne, and Leeds continue to do good work. The Engineering Conference, previously referred to, in which Students as well as members of all classes of the Institution will be invited to take part, will afford an opportunity for the Students to assemble as usual in London in the month of May.

The Collection of Paintings.

A portrait of the late Mr. Charles Blacker Vignoles, Past-President, has been presented by his son, Mr. Henry Vignoles. The portraits of the Past-Presidents now in the possession of the Institution are of great interest, and form part of the most valued property of the members. The Council beg leave to express a hope that the series may be rendered complete by gift or bequest of the portraits at present wanting of the Past-Presidents, and that, in future, succeeding Presidents will each in turn assist to maintain the completeness of the collection.

The Premises.

Since the date of the last Report the rooms have been completed and decorated, and at the end of December the entire effects of the Institution were housed in the new building. Of the structural arrangements it need only be said that, subjected to the test of a year's ordinary work, and of the conversazione that was held on the 15th and 16th July last, they have served their purposes conveniently and have ensured general comfort. The decorative treatment speaks for itself, and the Council trust the result may be deemed to justify their selection of the designs, and to do credit to the Architect and to those employed under him upon this work. The final stage of the operations contingent upon the re-building, is the arrangement of the large and ever-increasing stock of publications and documents, the completion of which process will be carried out during the recess.

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS.

Dr.	£.	s.	d.	£.	s.	d.	£.	s.	d.
To Balance, 1 April, 1896, viz.:—									
On Deposit				7,000	0	0			
Cash in the hands of the Treasurer . . .				1,282	14	6			
" " " Secretary . . .				14	0	5			
							8,296	14	1
INCOME.									
— Subscriptions received:—	£.	s.	d.						
Arrears, prior to 1 January, 1896	440	7	0						
For the year 1896	4,357	4	0						
For the year 1897	13,802	0	6						
				18,599	11	6			
— Minutes of Proceedings:—Re-payment for Binding, &c.				461	14	5			
— Library Fund				156	2	6			
— Dividends: 1 year on									
£	*Institution Dividends.*								
2,000 2¾% Consols . . .	53	3	4						
6,000 Metropolitan 3½% Stock	203	0	0						
6,000 Great Eastern Railway 4% Debenture Stock.	232	0	0						
6,000 Great Northern Ry. 3% Debenture Stock . .	174	0	0						
6,000 Great Western Ry. 4% Debenture Stock . .	232	0	0						
8,000 Lancs. & Yorks. Ry. 3% Ditto.	232	0	0						
6,000 London & N.W. Ry. 3% Debenture Stock . .	174	0	0						
8,000 Midland Ry. 3% Ditto .	232	0	0						
1,200 Twelve hundred £1 shares in Sir Wm. Armstrong, Whitworth Co., Ltd.—6 months' Dividend at 5% (new investment)	29	0	0						
£49,200 Nominal or par value.									
— Dividend on Stocks sold during the year:—									
4,000 2¾% Consols (6 months')	53	3	4						
2,000 Great Northern Ry. 3% Debenture Stock (6 months')	29	0	0						
1,400 5% Debenture Stock in Sir Joseph Whitworth & Co., Ltd. (1 year and 5 months) . .	95	13	2						
4,000 Four hundred £10 shares in Sir Joseph Whitworth & Co., Ltd.	385	10	0						
				2,124	9	10			
— Rents—No. 27 Great George St.				926	10	0			
— Interest on Deposit				14	10	7			
— Miscellaneous receipts				2	10	0			
							22,285	8	10
Carried forward							£30,582	3	9

from the 1st APRIL, 1896, *to the* 31st MARCH, 1897.

EXPENDITURE.

Cr. GENERAL EXPENDITURE.

	£.	s.	d.	£.	s.	d.	£.	s.	d.
By House and Establishment Charges:—									
Repairs:— General and restoring pictures	245	6	0						
No. 27 Gt. George St. .	38	19	6						
				284	5	6			
Rent of No. 27 Great George Street				600	0	0			
Rates and Taxes:—The Institution	882	6	8						
No. 27 Gt. George St.	206	9	4						
				1,088	16	0			
Insurance:—The Institution . .	65	7	3						
No. 27 Gt. George St.	2	14	6						
				68	1	9			
Rent of Telephone				20	0	0			
Lighting, Warming and Ventilating:—									
The Institution . .	346	18	11						
No. 27 Gt. George St.	12	19	10						
				359	18	9			
Refreshments at Meetings				96	0	9			
Assistance at Meetings				15	15	0			
Students' Meetings and Visits				186	1	3			
Household Expenses.				292	0	8			
Pressure-water for Lifts				14	11	0			
							3,025	10	8
— Postages, Telegrams, and Parcels				398	0	10			
— Stationery and Printing				907	13	1			
— Watt Medals				7	2	6			
— Stephenson Medals				7	2	6			
— Diplomas				31	6	1			
— Annual Dinner (balance of 1896 and part 1897) .				210	9	3			
— Conversazione				1,216	9	0			
							2,778	3	3
— Salaries				2,277	0	0			
— Clerks, Messengers, and Housekeeper				1,297	9	9			
— Retiring Allowances and Donations				1,032	0	0			
							4,606	9	9
— Library:—Books and Periodicals				364	4	1			
Binding				66	8	8			
							430	12	9
— Publications:—									
"Minutes of Proceedings," Vols. cxxiv., cxxv., cxxvi. and cxxvii.				8,306	1	7			
Charters, By-Laws, and Lists of Members . .				370	3	6			
							8,676	5	1
Carried forward . . .							£19,517	1	6

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS—*continued.*

Dr.				£.	s.	d.
Brought forward				30,582	3	9

Capital.

	£.	s.	d.	£.	s.	d.
To Admission-Fees	3,332	14	0			
— Life-Compositions	577	10	0			
— Sale of £4,000 2¾ % Consols	4,519	19	0			
„ „ £2,000 Great Northern Railway 3 % Debenture Stock	2,447	13	0			
„ „ £1,400 5 % Debenture Stock in Sir Joseph Whitworth & Co. Ltd. . .	1,540	0	0			
„ „ 400 £10 shares in Sir Joseph Whitworth & Co. Ltd. (part payment in cash)	3,000	0	0			
				15,417	16	0

	£.	s.	d.
Carried forward . . .	£45,999	19	9

from the 1st APRIL, 1896, *to the* 31st MARCH, 1897.

EXPENDITURE—*continued.*

Cr.				£.	s.	d.
Brought forward				19,517	1	6
By Legal Expenses:—						
Supplemental Charter	234	7	0			
Opposition to registration of proposed Institution of Civil and Mining Engineers	120	12	4			
Public Offices Site Bill	71	12	3			
Westminster Improvements Bill	32	11	10			
Palmer Scholarship	7	13	6			
Opposition to Architects' and Sanitary Registration of Buildings Bills	14	5	0			
General	53	17	2			
				534	19	1
— Inquiry as to Examinations	7	19	6			
— Interest on overdraft	11	11	8			
— Donation to Westminster Hospital	10	10	0			
				30	1	2
				20,082	1	9

CAPITAL.

	£.	s.	d.				£.	s.	d.
By return of Foreign Life Composition (in part)	23	12	6						
— Charges *re* Sale of Stock	0	11	6						
				24	4	0			
— New Building—									
Contract	14,269	13	0						
Decorations	2,349	6	3						
Architect:—Commission	849	6	5						
Clerk of Works	152	0	0						
Copy of Portrait of Telford	75	0	0						
Fixtures and Furniture	1,611	15	9						
Removing, Warehousing, &c.	392	11	8						
Miscellaneous Work and incidental expenses	99	18	1						
Rates and Taxes on temporary premises	5	9	0						
Lighting and Warming of ditto	14	10	11						
				19,819	11	1			
							19,843	15	1

	£.	s.	d.
Carried forward	£39,925	16	10

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS—*continued.*

Dr.		£. s. d.	£. s. d.	£. s. d.
	Brought forward			45,999 19 9
	Trust-Funds.			
	Telford Fund.			
£. s. d.	To Dividends:—1 year on			
5,439 11 0	2¾% Consols	144 12 4		
3,299 2 0	Ditto (Unexpended Dividends) . . .	87 14 0		
£8,738 13 0			232 6 4	
	Manby Donation.			
£250 0 0	Great Eastern Ry. 4% Irredeemable Guaranteed Stock		9 13 4	
	Miller Fund.			
3,125 0 0	2¾% Consols. . . .	83 1 4		
2,004 17 5	Ditto (Unexpended Dividends). . . .	53 6 0		
£5,129 17 5			136 7 4	
	Howard Bequest.			
£551 14 6	2¾% Consols		14 13 4	
	Trevithick Memorial.			
£103 0 0	2¾% Consols		2 14 8	
	Crampton Bequest.			
£512 15 11	2¾% Consols.		13 12 8	
	James Forrest Lectureship.			
£320 0 0	South-Eastern Ry. 5% Debenture Stock		15 9 4	
	Palmer Scholarship.			
1,381 1 6	Metropolitan 3% Stock .	40 1 0		
50 7 7	Ditto (Unexpended Dividends) . . .	1 2 0		
			41 3 0	
£1,431 9 1				466 0 0
				£46,465 19 9

from the 1st APRIL, 1896, *to the* 31st MARCH, 1897.

EXPENDITURE—*continued.*

Cr.

	£.	s.	d.	£.	s.	d.	£.	s.	d.
Brought forward							39,925	16	10
Trust Funds.									
By Telford Premiums	171	4	1						
— Telford Medals	18	0	0						
				189	4	1			
— Manby Premiums				46	16	5			
— Miller Prizes				71	16	7			
— Trevithick Premiums				19	19	6			
— Crampton Prizes				41	12	7			
— "James Forrest" Lecture (Fourth)	15	9	4						
" " " (Fifth) .	23	5	4						
				38	14	8			
— Palmer Scholarship— Purchase of £50 7 7 Metropolitan 3 % Stock				60	8	1			
							468	11	11
							40,394	8	9
— Balance, 31 March, 1897, viz.:—									
On deposit				5,000	0	0			
Cash in the hands of the Treasurer				1,063	19	7			
" " Secretary				7	11	5			
							6,071	11	0
							£46,465	19	9

Examined with the Books and Securities and found correct.

(Signed) A. C. Hurtzig, John G. Griffiths, F.C.A. } *Auditors.*

J. H. T. Tudsbery, *Secretary.*
12 *April,* 1897.

STATEMENT OF INVESTMENTS HELD 31 MARCH, 1897.

Institution Investments.

£			£.	s.	d.	£.	s.	d.
2,000	2¾% Consols	Cost	1,967	19	1			
6,000	Metropolitan 3½% Stock	"	6,517	15	0			
6,000	Great Eastern Railway 4% Debenture Stock	"	7,749	18	3			
6,000	Great Northern Railway 3% Debenture Stock	"	5,329	13	10			
6,000	Great Western Railway 4% Debenture Stock	"	7,476	12	6			
8,000	Lancashire and Yorkshire Railway 3% Debenture Stock	"	7,452	14	8			
6,000	London and North Western Railway 3% Debenture Stock . .	"	5,544	18	5			
8,000	Midland Railway 3% Debenture Stock	"	7,460	18	11			
1,200	1,200 £1 Shares in Sir Wm. Armstrong, Whitworth & Co., Limited	"	1,000	0	0	50,500	10	8
49,200								

Freehold of Institution Premises and New Building:—				
Cost, including buildings now removed . £121,993 19 2				
Valued by Messrs. Edward Ryde and Sons on the 14th August, 1896	..	88,000	0	0
		138,500	10	8

Note.—No value has yet been attached, for the purpose of this statement, to the Books, Furniture, Fittings, Pictures, &c., in the Institution Building nor to the lease of No. 27 Great George Street.

Trust Fund Investments.

Telford Fund.

£.	s.	d.			£.	s.	d.
1,945	19	0	2¾% Consols—	Acquired with bequest of . . .	2,000	0	0
3,479	12	9	do.	Converted from Government Stocks bequeathed	Bequest.		
13	19	3	do.	Purchased with bonus on conversion cost	13	11	3
5,439	11	0					
3,299	2	0	do.	Purchased with unexpended dividends	3,034	18	1
8,738	13	0					

Manby Donation.

£.	s.	d.		
250	0	0	Great Eastern Railway 4% Irredeemable Guaranteed Stock	Donation.

Miller Fund.

£.	s.	d.			£.	s.	d.
3,125	0	0	2¾% Consols—	Acquired with bequest of . . .	3,000	0	0
2,004	17	5	do.	Purchased with unexpended dividends . . . . Cost	1,850	2	4
5,129	17	5					

TRUST FUNDS INVESTMENTS—*continued.*

£.	s.	d.		£.	s.	d.
			Howard Bequest.			
551	14	6	$2\frac{3}{4}$% Consols—Acquired with bequest of . . .	500	0	0
			Trevithick Memorial.			
103	0	0	$2\frac{3}{4}$% Consols—Acquired with a presentation of .	100	0	9
			Crampton Bequest.			
512	15	11	$2\frac{3}{4}$% Consols—Acquired with bequest of . . .	500	0	0
			James Forrest Lecture Fund.			
320	0	0	South Eastern Railway 5% Debenture Stock acquired with a subscription of	510	0	0
			Palmer Scholarship.			
1,381	1	6	Metropolitan 3% Stock	Bequest		
50	7	7	do. do. Purchased with unexpended dividends . . . . Cost	60	8	1
1,431	9	1				

MEDALS AND PREMIUMS AWARDED.

Session 1896–97.

The Howard Quinquennial Prize to Hilary Bauerman, Assoc. M. Inst. C.E., in recognition of his work on the Metallurgy of Iron.

For Papers Read and Discussed at the Ordinary Meetings.

1. A Telford Medal and a Telford Premium to Herbert Alfred Humphrey, Assoc. M. Inst. C.E., for his Paper on "The Mond Gas-Producer Plant and its Application."
2. A George Stephenson Medal and a Telford Premium to George Edward Wilson Cruttwell,[1] M. Inst. C.E., for his description of "The Tower Bridge: Superstructure."
3. A Telford Medal and a Telford Premium to Colonel John Pennycuick, C.S.I., R.E., for his account of the "The Diversion of the Periyar."
4. Watt Medals and Telford Premiums to David Hay, M. Inst. C.E., and Maurice Fitzmaurice, B.E., M. Inst. C.E., for their joint Paper on "The Blackwall Tunnel."
5. A Telford Medal and a Telford Premium to Edward Clapp Shankland, M. Inst. C.E., for his Paper on "Steel Skeleton Construction in Chicago."
6. A Telford Premium to Hay Frederick Donaldson, M. Inst. C.E., for his Paper "Cold Storage at the London and India Docks."
7. A Telford Premium to William Ripper, M. Inst. C.E., for his Paper on "Superheated-Steam Engine-Trials."
8. A Telford Premium to Henry Willock Ravenshaw, Assoc. M. Inst. C.E., for his Paper on "Electric Lifts and Cranes."
9. Telford Premiums to John Edward Worth and William Santo Crimp,[1] MM. Inst. C.E., for their joint Paper on "The Main Drainage of London."

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[1] Have previously received Telford Premiums.

10. A Telford Premium to Samuel George Homfray, M. Inst. C.E., for his description of "The Machinery of the Tower Bridge."

FOR PAPERS PRINTED IN SECTION II OF THE PROCEEDINGS FOR THE SESSION 1896–97.

1. A Telford Medal and a Telford Premium to Thomas Holgate, Assoc. M. Inst. C.E., for his Paper on "The Enrichment of Coal-Gas."
2. A Telford Medal and a Telford Premium to Dugald Drummond,[1] M. Inst. C.E., for his "Investigation into the Use of Progressive High Pressures in Non-compound Locomotive Engines."
3. A George Stephenson Medal and a Telford Premium to William Cawthorne Unwin,[2] B.Sc., F.R.S., M. Inst. C.E., for his Paper on "A New Indentation Test for Determining the Hardness of Metals."
4. A Telford Premium to Major Smith S. Leach, Corps of Engineers United States Army, for his Paper "Inland Navigation in the United States."
5. A Telford Premium to Othniel Foster Nichols, M. Inst. C.E., for his Paper on "The Brooklyn Elevated Railway."
6. A Telford Premium to James Ramsay, M. Inst. C.E., for his description of "The Mushkaf-Bolan Railway, Baluchistan, India."
7. A Telford Premium to Harold Duke Smith, Assoc. M. Inst. C.E., for his Paper, "Transverse Strength of Large Beams of Yellow-Pine Timber."

FOR PAPERS READ BEFORE MEETINGS OF STUDENTS.

1. The James Forrest Medal and a Miller Prize to Alexander Hope Jameson, B.Sc., Stud. Inst. C.E., for his Paper on "The Strength of Materials," read before the Manchester Association of Students;
2. The James Prescott Joule Medal and a Miller Prize to Harold Wood Barker, Stud. Inst. C.E., for his Paper on "Cooling Reservoirs for Condensing Engines," read at the Institution;

[1] Has previously received a Telford Premium.
[2] Has previously received Telford Premiums and Telford and Watt Medals.

and Miller Prizes to the following, for Papers read at the Institution :—

3. Walter Beer,[1] Stud. Inst. C.E., for his Paper on "The Monier System of Construction;"
4. Henry Francis Brand, Stud. Inst. C.E., for his Paper on "The Inverness Section of the Inverness and Aviemore Railway;"
5. Harold Berridge, Stud. Inst. C.E., for his Paper on "Poole Harbour;"
6. John William Kitchin, Stud. Inst. C.E., for his Paper "Wells and Well Sinking;"

and, for Papers read before Local Associations of Students :—

7. Charles Henry Godfrey, Stud. Inst. C.E. (Manchester), for his Paper "Effects of Frost on Portland Cement;"
8. Robert Halley Garvie, B.Sc., Stud. Inst. C.E. (Manchester), for his account of the "Reconstruction of Latchford Lock Gates;"
9. Thomas Carter, Stud. Inst. C.E. (Newcastle), for his Paper on the "Theory of Two-Pole Continuous-Current Dynamo;"
10. Francis William Richard Hurt, Stud. Inst. C.E. (Leeds), for his Paper on "Superheaters."

[1] Has previously received a Miller Prize.

SUBJECTS FOR PAPERS.

SESSION 1897–98.

THE COUNCIL of The Institution of Civil Engineers invite Original Communications on the Subjects included in the following List, as well as on other questions of professional interest. This list is to be taken merely as suggestive, and not in any sense as exhaustive. For approved Papers the Council have the power to award Premiums, arising out of Funds bequeathed for the purpose, the particulars of which are as under:—

1. The TELFORD FUND, left "in trust, the Interest to be expended in Annual Premiums, under the direction of the Council." This bequest (with accumulations of dividends) produces a gross amount of £235 annually.

2. The MANBY DONATION, of the value of about £10 a year, given "to form a Fund for an Annual Premium or Premiums for Papers read at the meetings."

3. The MILLER FUND, bequeathed by the testator "for the purpose of forming a Fund for providing Premiums or Prizes for the Students of the said Institution, upon the principle of the 'Telford Fund.'" This Fund (with accumulations of dividends) realises nearly £140 per annum. Out of this Fund the Council has established a Scholarship,—called "The Miller Scholarship of The Institution of Civil Engineers,"—and is prepared to award one such Scholarship, not exceeding £40 in value, each year, and tenable for three years. No Paper will be received from a Student in competition for the Miller Scholarship and the Miller Prizes when he has become qualified by age, viz. twenty-five years, for election into the Corporation.

4. The HOWARD BEQUEST, directed by the testator to be applied "for the purpose of presenting periodically a Prize or Medal to the author of a treatise on any of the Uses or Properties of Iron or to the inventor of some new and valuable process relating thereto, such author or inventor being a Member, Graduate, or Associate of the said Institution. The annual income amounts to nearly £15. It has been arranged to award this prize every five years commencing from 1877. The next award will be made in 1902.

5. The CRAMPTON BEQUEST of £500, free of legacy duty, has been invested in the purchase of £512 15*s*. 11*d*. 2¾ per cent. consols, and the income arising therefrom is now £13 14*s*. This trust is for the purpose of founding "a Prize to be called the 'Crampton Prize,' so that the interest of the said legacy shall be annually expended in a medal or books or otherwise . . . . for presentation to the Author of the best Paper on 'The Construction, Ventilation and Working of Tunnels of Considerable Length,' or failing that then on any other subject that may be selected."

6. The balance of the TREVITHICK MEMORIAL FUND, amounting to £100 0*s*. 9*d*., has been accepted for a periodical Premium to be called after Richard Trevithick. This sum has been placed in £103 2¾ per cent. consols, upon which the interest is £2 15*s*. a year.

7. The JAMES FORREST MEDAL, founded in 1897, is endowed with the balance of a sum of money given by those who had served on the Council towards a presentation to Mr. Forrest on his retirement from the Secretaryship. The medal is to be awarded annually to a Student of the Institution who contributes the best Paper received from that class.

8. The JAMES PRESCOTT JOULE MEDAL is placed by the Trustees of the Endowment Fund at the disposal of the Council, in every third year, for award to a Student of The Institution, for the best Paper presented on an engineering subject, "preference being given to a Paper dealing with the transformation of energy." The medal will be at disposal next in 1900.

The Council will not make any award unless a communication of adequate merit is received, but will give more than one Premium if there are several deserving memoirs on the same subject. In the adjudication of the premiums no distinction will be made between essays received from members of the Institution or strangers, whether Natives or Foreigners, except in the cases of the Miller and the Howard bequests and the James Forrest and James Prescott Joule medals, which are limited by the donors.

LIST OF SUBJECTS.

1. The most economical Methods of Handling large masses of Excavation, as exemplified in modern canal construction.
2. The Measures necessary for the improvement of Canal Navigations.
3. The Methods adopted in carrying out large Dock and Harbour Works, with descriptions of the Plant employed.

4. The Appliances for Dredging and for Removing Rock in deep water, with details of the time occupied in the various operations.
5. The Application of Compressed Air, steam and hydraulic power to Rock-drills.
6. The Design and Construction of Railway Carriages, having reference to (*a*) lavatory accommodation; (*b*) provision for refreshments; and (*c*) sleeping arrangements.
7. The Modern Methods of Pumping compared as to cost and efficiency.
8. The Use of Steel in the Construction of large Tanks.
9. The Employment of Storage-Reservoirs in Irrigation and in the Conservation of Rivers.
10. The Purification of Sewage by precipitation, filtration, electrolytic, bacteriological and chemical processes.
11. The Use of Ash-bin Refuse in towns for the production of steam.
12. The Purification of large quantities of Water after its use in Manufactories.
13. The Production and Enrichment of Water Gas.
14. The methods of conveying and of using Natural Gas.
15. The Construction and Use of Water-Tube Boilers.
16. The Utilization of Heat (*a*) generated in the compression of air and other gases; (*b*) carried away by steam-engine condenser-water; and (*c*) contained in boiler-furnace flue-gases.
17. The Methods of Condensing Steam by the use of moderate quantities of water.
18. The Methods of removing Moisture from Steam, and of reducing losses by radiation from steam-pipes.
19. The Theory and Development of the Compound Steam-Turbine.
20. The Application of Oil- and Gas-Engines to tractive purposes on common roads and on tramways, and to the propulsion of vessels.
21. The Design and Construction of large Turbines.
22. The Forms of Turbine most suitable for small Falls.
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28. Recent improvements in the Manufacture of Armour-Plates.
29. The Strength of Steel Shafts, Tubes and Cylinders.
30. The Mining of Thin Seams of Coal.
31. The Underground Arrangements in Collieries.
32. The Influence of Coal-dust in contributing to Colliery Explosions.
33. The Use of Electrical Energy in working Mines.
34. The Drainage of Mines by Pumping and by Tunnelling.
35. The Extraction of Metals from their Ores by electrolytic processes.
36. Argentiferous Lead Smelting in Water-jacketed blast-furnaces.
37. The Methods of Gold-mining in California.
38. The Occurrence, Production and Uses of (*a*) Asbestos, (*b*) Arsenic, and (*c*) Mercury.
39. The Metallurgy of Chromium, Molybdenum and other rare metals, and their use in the Manufacture of Steel.
40. The design, construction, erection and working of Modern Stamp Mills.
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42. The most suitable Steam-power Equipments for Electric-light stations.
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45. The Regulation of Electric pressure in large lighting circuits as carried out at the engine, the dynamo, or the exciter.
46. The Theory and Practice of the Transmission of Power by Alternating Currents.
47. The Use of Electrical Motors for driving machines in textile factories and in engineering workshops.
48. The first cost, facility and economy of operation of Electrical Traction on Railways with heavy trains and on Tramways.
49. The Municipal Control of Tramways with a view to their working electrically, in conjunction with electric lighting.
50. The Construction and Working of Electrical Lifts and Cranes.
51. The Electrolytic Action of Return Currents in Electrical Tramways on gas- and water-mains, and the best means of providing against Electrical Disturbances.
52. The most suitable Alloys for the working parts of Pumps for lifting corrosive liquids from mines, etc.

53. The Methods of Preventing or Arresting the Corrosion of Hydraulic Rams of large diameter.
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63. The Use of Electrical Machinery for lighting and the transmission of power in warships and in the mercantile marine.
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JAMES FORREST, *Honorary Secretary*,
J. H. T. TUDSBERY, *Secretary*.

THE INSTITUTION OF CIVIL ENGINEERS,
Great George Street, Westminster, S.W.
October, 1897.

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Aspinall, J. A. F. No. 3,009.—The Horwich Locomotive Works of the Lancashire and Yorkshire Railway. With 3 Drawings and a Pamphlet. (Vol. cxxix. p. 309.)

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Hull, E., M.A., LL.D., F.R.S.
Humphrey, R. L.
Hutton, W. R.

I.

Illinois Mining Institute.
Imperial Institute.
Imperial University of Japan.
Incorporated Association of Municipal and County Engineers.
Incorporated Gas Institute.
Incorporated Institution of Gas Engineers.
India Office.
"Indian and Eastern Engineer."
"Indian Engineering."
Indian Meteorological Department.
Indian Telegraph Department.
"Industria, L'."
"Industrie, L'."
"Industrie électrique, L'."
"Industries and Iron."
"Ingegneria Civile e le Arti Industriali, L'."
"Ingeniero, El."
Institute of Chartered Accountants in England and Wales.
Institute of Chemistry.
Institute of Secretaries.
Institution of Civil Engineers of Ireland.
Institution of Electrical Engineers.
Institution of Engineers and Shipbuilders in Scotland.
Institution of Junior Engineers.
Institution of Mechanical Engineers.
Institution of Naval Architects.
Institution of Surveyors, Sydney.
"Insurance Spectator of London, The."
"Invention."
"Inventors' Review."
"Irish Builder."
"Iron Age, The."
"Iron and Coal Trades Review, The."
Iron and Steel Institute.
"Iron and Steel Trades' Journal, The."
"Ironmongery."
"Iron Trade Circular."
Ivatt, H. A.

J.

Jacobus, D. S., M.E.
Jenkins, R.
Jobson, C.
"Johannesburg Standard and Diggers News."
Johnson, F. R.
Jones, J. A., F.R.S.E.
Jones, T. G., B.Sc., Wh.Sc.
"Journal of Gas Lighting."

K.

Kaiserliches Patentamt, Berlin.
Keating, E. H.
Kempe, H. R.
Kennedy, R. G.
Kew Observatory.
King's College, London.
King's College, Nova Scotia.
Königliche bayerische Akademie der Wissenschaften.
Königliche sächsische Berg-Akademie zu Freiberg.
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Königliche technische Hochschule zu Stuttgart.

Koninklijk Instituut van Ingenieurs.
Kreuter, F.

L.

Landsberg, T.
Lang, G.
Langdon, W. E.
Langley, S. P.
Lanza, G.
Lapage, R. H.
Lass, A.
Law, H.
Law, H. H.
Leavitt, E. D.
Leeds Free Public Library.
Leicester Free Public Libraries.
Light-House Board, Washington, U.S.A.
"Lightning."
Lindley, W. H.
Literary and Philosophical Society of Liverpool.
Liverpool Engineering Society.
Liverpool Observatory.
Lockwood, C.
London County Council.
Longmans, Green & Company.
Longridge, C. C.
Longridge, M., M.A.
Loos, D. de., D.-ès-Sc.
Lovegrove, E. J.
Lyster, A. G.

M.

Macaulay, F. W.
McGill College and University, Montreal.
"Machinery."
"Machinery Market."
Maconchy, G. C.
McPherson, J. A.
Madras University.
Magyar Mérnök-és Épitész.
Malo, L.
Mance, *Sir* H. C., C.I.E.
Manchester Association of Engineers.
Manchester Literary and Philosophical Society.
Manchester Public Free Libraries.
Manchester Steam Users' Association.
Manitoba University.
Mann, J. R., *Jun.*
"Marine Engineer."
"Mariner."
Markham, C. C.
Marriott, W. K.
Martens, A.
Maschwitz, C.
Mason Science College, Birmingham.
Massachusetts Board of Railroad Commissioners.
Massachusetts Institute of Technology.
Massachusetts State Board of Health.
Master Car Builders' Association, Chicago.
Maxwell, W. H.
Mayne, C.
Mazoyer, —.
Melbourne Exhibition Trustees.
Melbourne University.
"Memorial de Artillería."
Mendès Guerreiro, J. V.
Mersey Docks and Harbour Board.
Meteorological Office, London.
Meteorological Office, Bombay.
Metropolitan Board of Water Supply and Sewerage, Sydney.

Meyer, E.
Michaëlis, W.
Michaelsson, F.
Michigan Mining School.
Michigan University.
Midland Institute of Mining, Civil and Mechanical Engineers.
Military Service Institution, U.S.A.
Milner, H. E.
Mines Department, Brisbane.
Mines and Water Supply Department, Melbourne.
Mines Department, Perth, W.A.
Mines Department, Wellington, New Zealand.
Mining Association and Institute of Cornwall.
"Mining Engineering."
Mining Institute of Scotland.
"Mining World."
Ministère de l'Agriculture, Paris.
Ministère des Chemins de Fer, Postes et Télégraphes, Brussels.
Ministère des Travaux publics, Paris.
Ministerie van Waterstaat, Handel en Nijverheid.
Ministerium der öffentlichen Arbeiten, Berlin.
Ministry of Public Works, Santiago.
Mitchell, H. F.
"Moniteur Industriel, Le."
Montreal Harbour Commissioners.
Morison, G. S.
Morsing, C. A.
Mountain, A. C.
Muller, J. V. S.

N.

National Association of Builders of the United States of America.
National Library, Buenos Ayres.
"Nature."
Navy Department, Washington, U.S.A.
Nederlandsche Vereeniging voor Electrotechniek.
Newcastle-upon-Tyne Public Libraries.
Newcombe, A. C.
Newell, F. H.
Newman, J.
New York State Board of Health.
New Zealand Institute.
New Zealand University.
Norris, W.
Norsk Ingeniør- og Arkitekt-Forening.
North, E. P.
North-East Coast Institution of Engineers and Shipbuilders.
North of England Institute of Mining and Mechanical Engineers.
Norwich Free Library.
Nova Scotian Institute of Science.

O.

Ocagne, M. d'.
O'Connor, C. Y.
Oesterreichischer Ingenieur-und Architekten-Verein.
Office of Mines, Hobart, Tasmania.
Oficina Meteorológica Argentina.
Olshausen, H.

Ordnance Committee.
Owens College, Manchester.

P.

Pacchioni, A.
Panjab University.
"Paper Maker."
Parry, J. W.
Parry, W. K., M.A., B.E.
Pasqueau, A.
Patchell, W. H.
Patent Office.
Paterson, M. M.
Peabody Institute.
Pennsylvania Railroad Company.
Permanent-Way Institution.
Pharmaceutical Society of Great Britain.
"Phillips' Monthly Register."
Philosophical Society of Glasgow.
"Plumber and Decorator."
Pole, W., Mus.D., F.R.S.
"Politecnico, Il."
Polyteknisk Forening.
"Portfeuille économique des Machines."
Pourcel, A.
"Practical Engineer."
Price-Williams, R.
Prideaux, *Sir* W. S.
"Progressive Age."
Prosser, R. B.
"Przegląd Techniczny."
Public Works Department, Allahabad.
Public Works Department, Bombay.
Public Works Department, Calcutta.
Public Works Department, Madras.
Public Works Department, Simla.
Public Works Department, Sydney.
Public Works Ministry, Cairo.
Pullen, W. W. F., Wh.Sc.

Q.

Queen's College and University, Kingston, Canada.
Queen's College, Belfast.
Queen's College, Cork.
Queen's College, Galway.
Queensland Branch of the Royal Geographical Society of Australasia.
"Queen's Quarterly."
Quinette de Rochemont, *Baron* E. T.

R.

Radcliffe Library, Oxford University Museum.
Radford, R. H.
Radice, A.
Raffard, N. J.
"Railway and Shipping Contractor."
Railway Commissioners of New South Wales.
"Railway Engineer, The."
"Railway Master Mechanic."
"Railway World."
Reade, T. M.
Reale Accademia dei Lincei, Rome.
Reale Istituto d'Incoraggiamento di Napoli.
Reale Istituto Lombardo di Scienze e Lettere.

Redgrave, G. R.
Reilly, C.
Reincke, —.
Reuleaux, E.
"Revista de Obras Publicas," Lisbon.
"Revue de l'aéronautique."
"Revue générale des Chemins de Fer."
"Revue industrielle."
"Revue technique, La."
Richards, E. W.
Rideal, S., D.Sc.
Ripper, W.
Robinson, H.
Robinson, J. C.
Roechling, H. A.
Ronna, A.
Ross, D. J.
Royal Academy of Sciences, Amsterdam.
Royal Agricultural Society of England.
Royal Artillery Institution.
Royal Astronomical Society.
Royal College of Physicians of London.
Royal College of Science for Ireland.
Royal Colonial Institute.
Royal Cornwall Polytechnic Society.
Royal Dublin Society.
Royal Engineers Institute.
Royal Geographical Society.
Royal Indian Engineering College, Cooper's Hill.
Royal Institute of British Architects.
Royal Institution of Great Britain.
Royal Irish Academy.
Royal Meteorological Society.
Royal Scottish Society of Arts.
Royal Society of Edinburgh.
Royal Society of London.
Royal Society of New South Wales.
Royal Society of Victoria.
Royal Statistical Society.
Royal United Service Institution.
Royal University of Ireland.
Russell, M.

S.

Sächsischer Ingenieur- und Architekten-Verein.
St. George, P. W.
Sanitary Institute.
Sauvage, E.
Schlatter, C. B.
Schönberg, A. C.
Schrödter, E.
Schröter, M.
Schweizerischer Ingenieur-und Architekten-Verein.
Sciuto, S.
Scott, A. de C., *Maj.-Gen.* R.E. (*retired.*)
Scott-Moncrieff, G. K., *Major* R.E.
Seefehlner, J.
Seguela, R.
Sennett, A. R.
Sewell, H. de Q.
Shaw, F. G.
Sheffield School of Medicine.
Shipmasters' Society.
"Shipping World."
Sidgreaves, W.
Simpson, J. B.
Sinigaglia, F.
Skinner, W. R.
Smith, W. Howard.
Smithsonian Institution.

Sociedad Científica Argentina.
Società degli Ingegneri e degli Architetti in Torino.
Società degli Ingegneri e degli Architetti Italiani.
Société d'encouragement pour l'industrie nationale.
Société de l'Industrie minérale de St. Etienne.
Société des Ingénieurs civils de France.
Société industrielle de Mulhouse.
Société nationale des Sciences naturelles et mathématiques, Cherbourg.
Société scientifique industrielle de Marseille.
Société technique de l'Industrie du Gaz en France.
Society for the Promotion of Engineering Education, Boston, U.S.A.
Society of Arts.
Society of Chemical Industry.
Society of Engineers.
South African Association of Engineers and Architects.
South African Philosophical Society.
South Australian Railways Commissioners.
South Wales Institute of Engineers.
Spolku Architektů a Inženýrů v království Českém.
Spon, E. and F. N.
Squier, G. O., Ph.D.
Stanford, E.
Stanley, H. C.
Starling, W.
State Engineer and Surveyor, New York.
"State Mining Journal." (*California.*)
"Steamship."
Stilgoe, H. E.
Stone, E. H.
Stradal, A. G.
"Street Railway Journal."
Sugg, W. T.
Surgeon-General, U.S. Army.
Survey of India Department.
"Surveyor, The."
Surveyor-General of the Colony of the Cape of Good Hope.
Surveyors' Institution.
Svenska Teknologföreningen.
Sweny, M. A., R.N.
Sydney Observatory.
Sydney University.
Symons, B.
Symons, G. J., F.R.S.
Syndics of the Cambridge University Press.

T.

Tasmanian Government Railways Department.
Tayler, A. J. W.
Technische Staatslehranstalt in Chemnitz.
Teive e Argollo, M. de.
Teknisk Forening.
Tetmajer, L.
Thomason Civil Engineering College, Roorkee.
Thomson, T. F.
Tokyo Library.
Tomlinson, S.
"Tool and Machinery Register."
Toronto University.
"Transport."
Tratman, E. E. R.
Trautwine, J. C., *Jun.*

"Travelers' Official Guide of the Railway and Steam Navigation Lines in the United States and Canada."
Trinity University, Toronto.

U.

Unione Tipografico - Editrice Torinese.
United States Artillery School.
United States Coast and Geodetic Survey.
United States Department of Agriculture.
United States Geological Survey.
United States Military Academy.
United States Naval Institute.
United States Naval Observatory.
United States Patent Office.
United States Weather Bureau.
Université de Gand.
University College, Bristol.
University College, London.
University College, Nottingham.
University of Bishop's College.
Unwin, *Prof.* W. C., B.Sc., F.R.S.
Utah Agricultural College.

V.

Vandervin, H.
Veillon, H.
Verein deutscher Ingenieure.
Verein deutscher Portland-Cement-Fabrikanten.
Verein für Eisenbahnkunde zu Berlin.
Verein zur Beförderung des Gewerbfleisses.
Vernon-Harcourt, L. F., M.A.
Victoria University, Manchester.
Victoria University, Toronto.
Victorian Railways Commissioners.

W.

Wade, W. R.
Walch, G. T.
Walther-Meunier, —.
War Department, Washington, U.S.A.
Waring, F. J., C.M.G.
Waring, G. E., *Jun.*
Water Commissioners of the City of Taunton, Mass.
Watkinson, W. H.
Weeks, J. D.
"West Australian Review."
Western Society of Engineers, Chicago.
Westminster Public Libraries.
Weston, E. B.
Wheeler, W. H.
Whipple, G. C.
Whitaker, W., B.A., F.R.S.
Whittaker and Company.
Williamson, A. A.
Wilson, H. M.
Wilson, J. M.
Wisconsin University.
Wolverhampton Free Library.
Woodward, H. B., F.R.S.
Woolmer, H. C.

Y.

Yorkshire College, Leeds.

Z.

Zeman, J.
Ziffer, E. A.
Zimmermann, H.

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	£.	s.	d.
Alexander, William (1895)	1	1	0
Allen, Gordon	1	1	0
Aspinall, M.	1	1	0
Barton, A.	1	1	0
Burne, E. L.	3	3	0
Carless, G. P.	1	1	0
Carter, R. E.	2	2	0
Cooke, S. B. R.	1	1	0
Crookes, B. H.	1	1	0
Davies, J. H.	5	0	0
Deane, H. H.	5	0	0
Doxat, L. C. J.	1	5	0
Henderson, G. R.	2	7	6
Henderson, William	3	3	0
Hill, H. A.	1	1	0
Hodge, E. C.	3	3	0
Jamieson, F. A.	5	5	0
Jennings, J. H.	50	0	0
Kimber, J. F. C.	2	0	0
Kirkland, T.	2	2	0
Lade, Alexander	1	1	0
Longhurst, F. H.	3	3	0
Carried forward	£97	2	6
Brought forward	97	2	6
Mittelhausen, C. J. A.	2	2	0
Perkins, J. E. S.	1	1	0
Perryn, G. H.	1	1	0
Raves, Brian A.	3	3	0
Ross, William (1895)	1	0	0
Salter, J.	1	1	0
Saunderson, F.	10	0	0
Scratchley, A. J.	5	5	0
Shand, Alexander	5	5	0
Sheilds, F. E. Went-worth-	1	1	0
Smith, H. V. C.	1	1	0
Spencer - Stanhope, P. B.	2	2	0
Stocken, A. L.	1	0	0
Straker, S.	1	1	0
Taylor, H. B.	10	10	0
Thomas, W. M.	5	0	0
Tomkins, W. S.	5	5	0
Wales, W. G.	1	1	0
Wood, J. H.	1	1	0
Total	£156	2	6

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*** *This Council will continue until April* 1898.

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(*The names of those deceased are printed in italics.*)

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EXTRA MEETING.

18 March, 1897.

JOHN WOLFE BARRY, C.B., F.R.S., President, in the Chair.

THE "JAMES FORREST" LECTURE.

Mr. J. Wolfe Barry, C.B., President, said it was his privilege to introduce to the members, Dr. Woodhead, who occupied a very distinguished position as Director of the Laboratories of the Royal Colleges of Physicians and Surgeons, and who had devoted great attention to the subject on which he proposed to lecture. He would not detain the members any length of time in introducing the lecturer; he would only say that the subject on which Dr. Woodhead was about to enlarge was one of peculiar interest to engineers at the present time, being one of those abstruse matters in which they all required light and leading from such a gentleman as the lecturer. The present was the fifth Forrest lecture at the Institution; and a new departure had been made in asking a distinguished member of another profession to give them the benefit of his knowledge. Up to the present time all the Forrest lectures had been delivered by members of the Institution, but he thought they would agree with the Council that the Institution was too catholic a body to draw the line at members of their own profession, and that they would all welcome among them any gentleman who could instruct them in any of the great subjects that were of interest to engineers and to the world at large.

"Bacteriology."

By German Sims Woodhead, M.D

Mr. President and Gentlemen,—My first duty, a duty which in this instance is a great pleasure, must be to thank you most heartily for the honour done me in inviting me to deliver the "James Forrest" lecture under the auspices of your Institution. I need scarcely say that I accepted the invitation with great readiness, not because I thought I was specially well fitted to deliver this lecture, but because I concluded that you, with your knowledge of the difficulties that surround the study of this subject, would, of your charity, condone most of my shortcomings.

My second duty must be to lay before you, as clearly as lies within my power, not merely a number of facts and details concerning bacteria and bacteriology, but also a short statement of the general laws that come into play in the carrying out of the great processes in Nature in which bacteria play so important a part.

In this world of ours, we, as some of its inhabitants, are too prone to take a somewhat one-sided view of the great facts we observe and of such parts of the fundamental laws that control the operations of great mother Nature as we are able to understand. We are too anxious to obtain all we can that conduces to our advantage, but we do not manifest an equal or reasonable readiness to accept or to attempt to guide the forces that appear to work to our disadvantage. In nothing is this more forcibly demonstrated than in our way of looking at the work done by bacteria. We almost always associate these bacteria and the processes they set up, with the disagreeable side of Nature and her works. We accept them as the ultimate causes of certain forms of deadly disease, and as the potent factors in bringing about putrefactive processes; but we seldom bear in mind the invaluable work they do in keeping the world sweet and clean for us, and in maintaining constant circulation of organic matter from the dead condition to the living, and from the living to the dead. If for our purpose to-night we look upon the world as one

Note.—The lecture was fully illustrated by lantern slides, many of them photomicrographs, some of which were lent by Mr. Pringle and Dr. Kanthack, to whom the lecturer expressed his indebtedness.

vast chemical laboratory in which processes of analysis or breaking down, and synthesis or building up, of organic material are constantly going forward, we shall be in a position to form some idea of the part that bacteria play, and of the many obligations under which we are placed by these organisms—very insignificant in size, but wonderfully potent in activity. As Pasteur pointed out, without their aid we should be unable to continue in existence. The animal and vegetable world would long since have perished from sheer inanition or starvation, and the work of the world as a great laboratory would have come to a standstill.

At the same time it must be remembered that, even in the best conducted of laboratories, many of the processes set up and experiments carried out involve a breaking of glass and the production of what can only, by the greatest stretch of courtesy, be called smells; so in Nature's laboratory, everything does not go on smoothly and to the advantage of man, beast and plant. Indeed, it seems as though there was a great tendency on the part of some of the agents and forces at work in this laboratory to go wrong, as soon as they are ignorantly interfered with in any way, and unless, when set to do special work by us, they are constantly kept under the strictest and most intelligent control. Once, however, understand them, and they are the most perfect servants that can be obtained. In this laboratory the retorts and test-tubes are the tissue cells of plants and animals; the re-agents are the powers within these cells, and sunlight, water, and fresh air, and the great workers in the laboratory are the various forms of animal and plant life, the latter of which are actively engaged in building up highly organised substances from the simplest elements or compounds, doing the preliminary work and preparing complex food stuffs for the use of animals, which in turn convert the energy stored up in plants into kinetic energy—energy utilized by them in carrying them from point to point, in enabling them to do various kinds of physical work, and in maintaining a regular temperature even under the most unfavourable conditions. All this is done at the expense of the highly organised vegetable materials that are taken into the bodies of these animals, by which a certain proportion of still more highly organised substances are built up, though some of their effete matter may consist of comparatively simple molecular combinations. Bacteria occupy a kind of intermediate position between the two; in many respects they resemble plants, but in others they are more like animal organisms, especially in that they have the power of breaking down elaborate compounds, from

which, on the one hand, they may form complex unstable substances, which eventually may become disintegrated into very simple chemical bodies; whilst on the other, they may bring about this disintegration in a much more direct and simple fashion. They have the power of taking up oxygen, some directly from the air, others from bodies containing large quantities of this element. From the albuminoid substances they may build up complex poisonous products of a most virulent nature, whilst they also have it in their power to break down highly complex organised animal and vegetable tissues, taking out of them what they require for their own use, and so arranging the parts that are left that they in turn are readily broken down into simple gases and water. So important is their function in this direction, that it has long been recognised that without the aid of bacteria it would, by this time in the world's history—in fact, long before this—have been a difficult matter, if not an impossibility, for either plants or animals to obtain food of any kind. It is then only through the agency of bacteria that the essential elements of the food of plants and animals are kept in circulation; it is by their action and through their aid that the higher plants are enabled to obtain nourishment, and it is by them that all dead organic matter, both plant and animal, is broken down by fermentative or putrefactive processes, and converted into materials assimilable by plants. In these processes the fermentative agents or bacteria act as providers or jackals for the higher plants, and therefore indirectly for us. It has been said that if we had eyes which could magnify 1,000 diameters (1,000,000 times) we should be able to see around us, in the air, in water, in the dust, and in our very food, numberless bacteria of various shapes and sizes, each doing some special kind of work, which, well or ill directed, conduces to our welfare or our disadvantage, as the case may be. Let us now consider for a few moments the history of the discovery of these wonderful organisms.

It was not until about the middle of the seventeenth century that the first records or descriptions of bacteria occur. From time to time before that there had undoubtedly been suggestions that small worms or animalculae were concerned in the production of fevers, plagues and similar diseases; indeed, we find that minute organisms (to which fanciful names are given) were freely associated with the plague of 1664–6, and were spoken of as having been observed under the lenses that were then at the disposal of scientific investigators. How difficult it was to gain any accurate conception of the form of these minute organisms

will be understood when I state that Athanasius Kircher in 1671 had only simple lenses which magnified some thirty-two times, whilst to-day the bulk of the work on bacteriology is done with lenses magnifying from five hundred to one thousand diameters. The epoch-making event in the study of bacteria was the manufacture by Leeuwenhoek, a Dutch merchant, of lenses with which he constructed the best microscope that had been manufactured up to that time. With this microscope he carried on a series of most elaborate investigations on the structure of plants, of hairs, of animal tissues, in fact, of every substance on which he could lay his hands, many of the results of which he communicated, either directly or through his friends, to the Royal Society; and during the course of his investigations he, in 1675, described living forms of such extreme minuteness that other observers, even following the accurate and lucid descriptions he gave, were not able to confirm his results. In 1683, however, he described and depicted minute organisms in material taken from his own teeth, descriptions and depictions which still stand as accurate representations of bacteria. After describing in detail his dental toilet, he says—"by these means my teeth are so clean and white that few persons of my age" (nearly fifty years) "can show so good a set, nor do my gums ever bleed although I rub them hard with salt, and yet I cannot keep my teeth so clean but upon examining them with a magnifying glass I have observed a sort of white substance collected between them, in consistence like a mixture of flour and water. In reflecting on this substance I thought it probable (though I could not observe any motion in it) that it might contain some living creatures. Having, therefore, mixed it with rain-water, which I knew was perfectly pure, I found to my great surprise that it contained many very small animalcules, the motions of which were very pleasing to behold. The largest sort of them is represented at A (giving the figure), and these had the greatest and quickest motion, leaping about in the fluid, like the fish called a jack; the number of these was very small. The second sort are represented at B; these often had a kind of whirling motion, and sometimes moved in the direction represented by the dotted line; these were more in number. Of the third sort I could not well ascertain the figure, for sometimes they seemed roundish but oblong, and sometimes perfectly round. These were so small that they did not appear larger than represented at E. The motion of these little creatures, one among another, may be imagined like that of a great number of gnats or flies sporting in the air. From the appearance of

these, to me, I judged that I saw some thousands of them in a portion of liquid no larger than a grain of sand, and this liquid consisted of eight parts water, and one part only of the before-mentioned substance taken from the teeth." Leeuwenhoek's microscopes magnified from 40 to 160 times. At that time he had not made up his mind as to the exact nature of these organisms; he spoke of them as living animalculae but in some of them he was unable to detect the slightest movement or any sign of life, nor did he theorise as to the meaning of the presence of these organisms in the situation in which he found them, though later, in 1713, he appeared to be under the impression that the organisms seen in the teeth were conveyed into the mouth by drinking-water that had been stored in barrels. Leeuwenhoek's observations are accepted as reliable to the present day, but the theorists who followed him soon left the firm ground of observation and launched into speculation so ridiculous that bacteria became the objects of ridicule, much as in recent years when such ill-considered and ridiculous speculations have been advanced as to their origin and exact nature. Previous to the description of the organisms given by Leeuwenhoek, worms and large animalculae had, on very inadequate grounds, been assigned as the cause of disease, of fermentation and of putrefaction, but Nicholas Andry, a true pathologist, reviewing a work on "Contagium Animatum," by Kircher, pointed out that Leeuwenhoek's bacterial animalculae, or germs, in all probability played a much more important part in setting up these various processes. He pointed out that air, water, vinegar, fermented wine, old beer and sour milk were all full of germs; and he even went so far as to say that the blood and pustules of small-pox also contained them, and that other diseases, such as the plague, were the result of the activity of these organisms, and he indicated that the method of treatment of such diseases was to kill the germs that brought them about. Varro and Lancisi about this time promulgated a theory as to the causation of malaria, which they said was due to invisible animalculae which inhabited the air, lying over and round marshes and swamps, thus foreshadowing the malarial organism described by later Italian and French investigators. So extraordinary was the mixture of truth and error contained in these various observations that the whole theory of the bacterial causation of disease, fermentation and putrefaction came to be most freely satirized, and the germ theory of disease was almost laughed out of existence. In 1726 there was published in Paris a pamphlet, which, whilst drawing attention to

the subject, made such fun of germs that some of the chapters, with modifications, might almost have been published ten years ago when the scoffers at bacteria had scarcely as yet had their evidence undermined. In this work these small organisms were derisively named "fainter," "body-pincher," "ulcerator," "weeping-fistula," and the like; intellectual and moral attributes were assigned to them, and a good general laugh was obtained at the expense of the doctors. On the other hand, a number of thoughtful men who looked beneath the surface saw much that was valuable in Leeuwenhoek's observations and his successors' speculations. Linnaeus, for example, maintained that as Leeuwenhoek's observations were undoubtedly accurate, the organisms that he described must play some part in altering the medium from which they extracted their nutriment, and in which they were evidently multiplying abundantly. He was followed by an Austrian doctor, Marcus Antonius Plenciz, of Vienna, who pointed out that associated with each specific disease there was, in all probability, a specific infective germ; thus, although the scarlet-fever germ should always be associated with scarlet fever, the same germ or seed could never give rise to small-pox. These germs were, he maintained, disseminated through the air; they could multiply in the body, and could thus set up the diseases of which they were assumed to be the causal agents. In the same way he ascribed to specific germs the various forms of putrefaction and fermentation, and "came to the conclusion that they were the result of the development, multiplication, and carrying on of the functions of nutrition and excretion by these germs, the products of fermentation being the volatile salts set free by the organisms, which, multiplying rapidly by forming seeds or eggs, rendered the fluid in which they developed thick, turbid, and foul." At this stage the question remained for over half a century, and it was not until well on into the nineteenth century (after 1831) that any real advances were made in systematizing our knowledge of bacteria, and in classifying the organisms that had already been described.

Before going further into the history of bacteria, it may be well to state in a few words what is the structure of these organisms, what is their relation to the media in which they live, and how they act in bringing about changes in these media. I throw on the screen a number of the more important forms of bacteria, from which you will see that some of them are rounded micrococci, as they are called, or small spheres; some of them are ellipsoidal, others are rod-shaped, others again threadlike, and a number of these threads assuming spiral or screwlike forms.

Then it will be noted that some are pear-shaped, others lemon-shaped, each of these forms being associated with different groups of bacteria, though several forms may be met with in the same series of organisms; thus the diphtheria bacillus may assume the form of short, slightly-curved rods with rounded ends, in other cases it is spindle-shaped with pointed ends; again it may be wedge-shaped, or, as the cultures grow older, it may, as seen in a stained specimen, assume the form of an Indian club with the handle painted in light and dark rings. Other organisms assume several forms regularly and consecutively, first appearing as small round cocci or spheres, these growing into longer rods, which in turn may extend into long threads, or may become club-shaped through swelling of a portion of the organism. These bacteria are classified as amongst the lower fungi. Owing to the fact that they multiply by a process of division transverse to the longitudinal axis (in the case of the rod forms) they are sometimes spoken of as fission fungi,—the "schizomycetes" of the Germans. The micrococci or rounded cells, the simplest form of all bacteria, are seldom more than 1 μ, about the $\frac{1}{25,000}$ part of an inch, in diameter. The rods or threads have about the same diameter, the length usually being from three to four times the diameter of the organism. There are, however, very marked deviations from these measurements; the above figures are given as representing the average size, and cannot be applied to special organisms.

At first sight it would appear that there can be little differentiation of structure in such minute organisms. You are aware that our bodies are made up of small cells in which, by careful microscopic examination, well marked and characteristic structural details have been observed; even our blood contains an enormous number of small cells and corpuscles, which, however, can only be distinguished under fairly high powers of the microscope. When I tell you that the red blood corpuscle is from five to nine times as large as the micrococcus, of which the above measurements have been given, whilst the white corpuscles may be twenty, or even more, times as large, some idea of the minuteness of these bacteria may be obtained. From a simple calculation we arrive at the fact that it would take about 500 millions of these organisms laid side by side to cover a postage stamp (625 millions to the square inch). These bacteria, like all other cells—animal and vegetable—are composed of a substance which in many respects resembles the albumen or white of egg; it is described as a vegetable albuminoid or protoplasm. It contains: water 84·81 per cent., albumen 13·207 per cent., fat 1·198 per cent., ash 0·638 per

cent., and extractives 0·327 per cent., the albumen being made up of carbon 52·32 per cent., nitrogen 14·75 per cent., and hydrogen 7·55 per cent.

This protoplasm, when in a very young condition, is jelly-like, perfectly transparent, and somewhat more refractile than water; in some cases it may be finely or coarsely granular. This mycoprotein, as it is called, or fungus protein, is not always of exactly the same composition. Minute granules of chlorophyl—the green colouring matter of leaves—small particles of fat or starch, sulphur granules, or particles of pigment, may be seen lying embedded in this vegetable albumen, which is, however, the basis and active portion of the cell. For the reason that they have a somewhat higher refractive index than water, these organisms may be examined in an unstained condition; but, for our purposes, it is better to stain them with one of the aniline dyes. The centre of the jelly-like speck is usually very deeply stained by these dyes, indicating that physiologically this is the most active part of the cell; surrounding this is a kind of membrane which is less deeply stained; this membrane contains a considerable quantity of cellulose similar to that found in the hard covering of the vegetable cells of the higher plants. This sheath or membrane varies somewhat in its physical characters, being sometimes elastic or pliable, at other times stiff and rigid. It is sometimes continuous over the whole organism, whilst in others it appears to be perforated by a series of pores through which minute threads of the central protoplasm appear to pass. Organisms in which this is seen may be compared to the foraminifera with their calcareous shells through which minute processes of protoplasm are from time to time extruded. Between the stained central portion and the outside membrane there may sometimes be seen a narrow unstained area; whether this is the result of artificial treatment or whether it is a kind of modified protoplasm shading off into the cellulose membrane, is somewhat difficult to determine, and it is quite possible that the character of this clear band may vary in different organisms. Those of you who have noted the result of putrefactive changes in meat, in soups, and during the making of beer, will have observed that there frequently appears, as putrefaction goes on, a slimy or jelly-like mass. On microscopic examination this is found to be made up of an enormous number of micro-organisms, each one surrounded by a clear soft jelly-like substance which does not stain like the rest of the organism; such masses are spoken of as zooglea masses, or living glue. I throw on the screen examples of this curious change. In

the ray-fungus—the fungus concerned in the production of wens and wooden tongue in cattle—as this swelling of the outer sheath takes place, we have the formation of a club-like organism, which, arranged in radiating groups, gives rise to the ray-fungus appearance. The clubbing or thickening in this case is due to the swelling of the sheath toward the outer ends of the radiating rods. This, roughly speaking, is the composition of the simple micro-organisms and of those which have no special colour characteristics when seen with the naked eye in large masses. There are, however, numerous organisms, which viewed in bulk are distinctly coloured red, magenta, yellow, brown and blue. Sometimes this colour is confined entirely to the sheath of the organism and is not soluble in ordinary re-agents; in other cases the colouring matter escapes from the cells into the surrounding medium as in the case of blue pus, blue milk where a peculiar smoky green or blue is found pervading the surrounding gelatine in which the organisms are growing; whilst, as the cladothrix dichotoma, one of the water organisms, grows in pure culture in gelatine, a beautiful clear brown colour appears which, it is said, is due to the separation of oxide of iron from the water by the organisms. In a few cases the sheath of the bacillus is not merely altered myco-protein; in the anthrax bacillus, for example, it contains no sulphur and is more like vegetable casein or the mucin found in the embryonic tissues of animals.

So much for the general structure. Coming now to special features of bacteria, we find, as Dallinger long ago pointed out, that certain of them are provided with delicate flagella, which are supposed to have the function of propelling them from point to point as they grow in fluid media. They are found adorning a much larger number of bacteria than was at one time supposed, and additions to the list of flagellated organisms are constantly being made. The ordinary bacillus of the colon (1 to 4), the typhoid bacillus (a much larger number), the cholera organism, and the organism of tetanus, may be taken as types, in which flagella are well seen. By special methods of staining with nitrate of silver, or with the aniline colours and special mordants, delicate threads, single or in groups, may be demonstrated as they come off from the ends or sides of these bacteria. When single the delicate threads are seldom numerous; but when they come off in pairs or small bundles a very large number, as many as twenty, may be observed. In such a case, however, they appear to come off in little groups, and Kanthack has described what he calls primary and secondary flagella; the

bundles apparently forming the primary flagella, and the single threads into which these bundles are divided, being described as secondary. The exact relation of the flagella to the protoplasm of the organism, whether they are developed directly from the protoplasm and pass out through the openings or pores already mentioned, or whether they are merely secondary modifications of the external membrane, as yet remains doubtful. From what we know, however, of other flagella and cilia, and from recent observations on the arrangement of the pores in the membrane, and the relation of the flagella to these pores, it is to be anticipated that they are usually, at any rate, processes directly continuous with the central protoplasm of the organism. At one time it was supposed that these flagella were formed only in organisms that have a special affinity for oxygen; but within the last couple of years it has been pointed out that the tetanus bacillus, the organism which grows best where free oxygen is excluded, often presents beautiful ciliated forms, although—and this is an important fact—the organism remains non-motile when examined under the microscope in the presence of oxygen. How it behaves when oxygen is excluded has not yet been determined. Even those bacteria which have an affinity for oxygen appear to lose their cilia as soon as they leave the surface and no longer require to move about in order to obtain this substance.

It has already been mentioned that the simplest form of multiplication of bacteria is by the cutting up of the organism into short lengths, which, in the case of the rod, after again increasing in length, becomes constricted in its middle, and ultimately may become divided completely or partially; in the former case a couple of short single rods are formed; in the latter, when the division goes on rapidly, chains of considerable length are the result. In spiral forms, as in the case of the cholera organism, the segments into which the longer rods divide are usually curved or comma shaped. The rounder organisms may divide in the same way that the rod-like organisms do, but in addition they frequently divide in the direction of two dimensions of space, when, of course, they may form a thin layer, or in three dimensions when they form cubes or masses. This multiplication by fission, or vegetative multiplication, as it is called, appears to take place only when all the conditions favourable for the nourishment of the organism are present, and in some organisms which are usually maintained in these favourable conditions it appears to be the only method by which they can multiply, though as yet it is impossible to speak absolutely definitely on this point. In certain organisms

however, especially when the conditions become unfavourable to the existence of organisms, a special and more complicated method of reproduction and permanent preservation of the species comes into play—spore formation.

In spore formation the protoplasm of the organism first becomes distinctly granular, then in the centre of the granular mass a small bright point appears which gradually increases in size until its diameter may be greater than that of the original organism. This bright mass, which may be round, ovoid, or in some cases even rod-shaped, is the resting spore or egg or seed of the bacterium by means of which the species may be continued after the rods, in their unfavourable surroundings, have perished. These spores are of very great importance, because they present a most remarkable resisting power to the action of chemicals, heat, and drying. When anthrax organisms, in which no spores have been developed, are dried they are very rapidly killed off, whilst exposure to a very moderate temperature or weak solutions of carbolic acid, or corrosive sublimate, ensures their rapid destruction. Spores, however, may, some of them, be exposed to the action of boiling water for several minutes without succumbing; they will withstand the action of powerful chemicals, and if they are then placed in favourable surroundings, they will still develop into the less resistant but more active form of organism. As an example of the importance of this spore formation, I may mention what takes place in the case of the splenic fever bacillus that is found in cattle. When an ox dies of anthrax there are found in its blood an enormous number of short thick rods, the anthrax bacilli. If a drop of the blood be taken from a blood-vessel immediately after death, the rods will be found on microscopic examination to contain no spores, that is, there are none of these bright points in the substance of the rod, and the animal, if buried at once before any blood or discharges from the body can get on to the land where the animal has died, will not be a source of infection; the putrefactive organisms that develop being sufficient to kill off the anthrax bacilli that are in the blood. If, however, the animal be cut into and blood be allowed to escape so that the organisms come into contact with the air and the condition of the blood is altered in such a way that the nutritive supply of these organisms is gradually altered or cut off, spores immediately begin to develop in the bacilli, and, as soon as this takes place, it is an exceedingly difficult matter to get rid of the disease; mere burial is certainly not sufficient, as the spores are not affected by the putrefactive organisms and products; they retain their vitality and only wait

for more favourable conditions again to develop into the active and virulent anthrax organism. The knowledge of this fact, of course, has a most important bearing on the treatment of carcases of animals that have succumbed to anthrax. Other forms of spores of a less resistant character have been described, but it is scarcely necessary to do more than mention them, as they are not yet accurately understood.

As to the effects of temperature upon micro-organisms, it has been found that most of the saprophytes (those that grow upon dead matter) flourish most luxuriantly at the ordinary temperatures of air and water, whilst the parasites, or disease-producing bacteria, grow and multiply most rapidly at the temperature of their animal or plant hosts. Most of these are killed at a temperature of 60° C. (140° F.). Certain bacteria, however, especially those found in soil and river mud, develop readily at 60° or 70° C. and flourish most luxuriantly at 50° C. Globig, and again quite recently A. Macfadyen, have shown that there are numerous organisms which can exist at temperatures even higher than this, in spite of the fact that they contain no spores. Of the spore-bearing organisms I have already shown the tetanus bacillus and the anthrax bacillus, both of which are pathogenic or disease-producing; I may also mention the bacillus subtilis, or hay bacillus of the Germans, one of the bacilli found especially in hay infusions, which appears to be associated with the digestion and breaking down of organic matter in the process of putrefaction.

We have not time to go into much greater detail as regards these structural characteristics of micro-organisms. I must however briefly describe some of the principal actions of these micro-organisms, in order that we may understand the rôle they assume in the process of putrefaction, fermentation and disease. Let us first take a character or property that can be readily demonstrated. If a drop of water be mixed with a quantity of melted jelly, and then the mixture be spread out in a thin layer in a glass dish, protected from air and dust, and the jelly be allowed to set, it will be found at the end of a few days that little points of growth may be observed. As a rule each of these points, or colonies, as they are called, is developed from a single organism, so that we have dotted over the surface of the gelatine little colonies, each of them derived from one of the organisms that was present in the orginal water; we are then able to study the characteristics of each organism as it grows. It will be observed that some of the organisms are perfectly colourless, but some assume a yellow colour, others may be red, others brown, others blue, whilst, as already noted, around

some of them the gelatine is stained, the colour being diffused from the organisms into the surrounding nutrient medium. These organisms, then, have the power of developing colouring matter; they have a chromogenic function, different organisms producing different forms of colouring matter. This is a function which is of course very readily observed, and therefore we have taken it as an example. On examining some of the other colonies it will be found that around them the gelatine has become softened, and in some cases in place of a colony dotted on the gelatine we find a little funnel-shaped depression containing a turbid or cloudy liquid. On examining this cloudy liquid under the microscope we find that it is teeming with bacilli or micrococci, usually actively motile. Some of these organisms, then, have the power of liquefying gelatine, and it is supposed that they exert this power through the agency of a kind of peptonising ferment, a ferment which in many respects appears to be similar to the juice formed in the stomach of man and animals, in which there is, as most of you are aware, a substance called pepsin, which dissolves or digests the food taken into the stomach. Such organisms have this power of producing a digestive fluid which is capable of acting very vigorously. In this most important function rests the power of bringing about the first stage of breaking down in the putrefactive process, and upon it depends the important part that these organisms play in the disposal of organic matter of all kinds, either naturally in the ground, or artificially in the various methods of disposing of sewage without the addition of chemical substances that have been recently suggested and applied.

If now we take certain organisms, such as the bacillus coli communis and seed it into gelatine, in which is placed a small quantity of grape-sugar, and then, melting the gelatine, add a weak solution of soda and litmus, sufficient to give a faint blue tinge to the mixture, and put the tube aside, we shall find that after two or three days two things occur: little bubbles of gas make their appearance in the gelatine, and these become so large that they may cause the gelatine to be split up, whilst near the surface the gelatine loses its blue colour and becomes distinctly red, showing that an acid has been formed. In the deeper layers to which the oxygen of the atmosphere can gain no access, no acid is formed. We thus see that this organism has the power of so breaking up the sugar by abstracting part of its molecule that it becomes an unstable substance. An acid is produced, and bubbles composed of marsh-gas and carbonic dioxide, or similar substances, are formed.

We have already mentioned that bacteria may be roughly divided into two classes—those which have the power of taking up oxygen from the air, and those which, although they require oxygen, as a rule obtain it from carbo-hydrates or from substances that contain a considerable quantity of oxygen in their composition, but which, deprived of their oxygen, rapidly break down to form substances of a less complex nature. It must be remembered, however, in this connection that no hard and fast line can be drawn between aerobes and anaerobes, as they are called—that is, between those organisms that require air and those organisms that can do without it, as under certain conditions an aerobic organism can lead an anaerobic existence, that is, can so far adapt itself to circumstances that when it is removed from air it makes violent efforts to obtain its oxygen from substances that contain oxygen in considerable quantities, taking them up best, of course, from those substances in which the oxygen is in a condition of loose combination; whilst, on the other hand, an anaerobic organism may grow fairly luxuriantly in the presence of air, although it is found that, under such conditions, it does not give rise to its characteristic products. Those organisms, which have the power of adapting themselves to their surroundings, are usually described as facultative aerobes and anaerobes; but although they can so far adapt themselves to the altered conditions, their life history and the results of their vital activity are considerably modified. Let us take as an example one that actually occurs in nature. If instead of water, as above, some surface soil is taken for the seed material for gelatine plates, the individual organisms contained in the soil are isolated; if, at the same time, a very minute fragment of this soil be put into gelatine containing a small quantity (2 per cent.) of grape sugar, or a still smaller quantity (½ per cent.) of formate of soda, two things will soon be noticeable. In the gelatine plate culture, especially if the layer of gelatine be of some little thickness, it will be observed that on the surface numerous colonies grow with very great rapidity, some of them producing colour, others of them liquefying the gelatine, the whole of the organisms on the surface showing luxuriant growth. Just beneath the surface of the gelatine, and down in its substance, will be seen a number of small brown points, which are certainly colonies of organisms; but they progress so slowly and to such small size that it is evident that the conditions for their growth are not so favourable as are those on the surface, the only difference in this case being, apparently, that those on the surface have a plentiful supply of oxygen, whilst those in the depth do not receive this

supply, although there is a small quantity, or they could not grow at all. Now, examining the formate of soda gelatine in the test tube, the organisms on the surface will still be seen to be growing, though not so luxuriantly, as a rule, as on the plate. Near the surface round colonies may also be seen; but down in the substance of the gelatine large colonies, sometimes liquefying the gelatine, sometimes producing gas in considerable quantity, are found. These are the anaerobic organisms which are breaking down the gelatine in the absence of air, just as those on the surface break down the gelatine in its presence. It will be found that in soil taken from very near the surface the number of anaerobic organisms, as compared with the aerobic organisms, is comparatively small. If, however, we take soil from a greater depth and treat it in the same way, the proportion of anaerobic to aerobic organisms is much larger, and going still deeper we come to a layer in which practically only anaerobic bacteria are found, whilst in deeper layers still there are no organisms of any kind.

In nature the process of decomposition of organic matter goes on most readily in these superficial layers of earth, and in the presence of the atmosphere; and the porous soil may be said to take the place of spongy platinum, in which, as we know, oxidation takes place very readily. The upper surface of this porous soil, usually well supplied with air and moisture and organic matter, is a capital feeding-ground for micro-organisms, which, breaking up its materials, oxidise them into substances which are capable of being utilized by plants. Most of the organic matter brought to the surface of the soil is broken down by these aerobic organisms, air being carried down along with the rain or sewage, and then, as this organic matter is broken up, some of its constituents are used by the bacteria, and others are, during the breaking down of the molecule, left in a nascent condition ready for oxidation by the air that has been left by the organisms. The anaerobic organisms found in the deeper layers of the soil, as we have indicated, give rise to a second kind of decomposition. A certain proportion of the organic matter escapes the action of the aerobic organisms, but it has still to run the gauntlet of the anaerobes. It is assumed that having been washed deeper into the soil and living as it were at some distance from the atmosphere, these anaerobic organisms (originally aerobic) have been unable to obtain free oxygen, and have thus been compelled to develop the power of wresting oxygen by force, as it were, from the oxygen-containing bodies that come down to them from the surface, usually using part only of the combined oxygen, and setting free another part

to be used up in the oxidation of portions of the organic matter that still remains. So completely do these organisms use up the food that has come from the surface that at a depth of about 12 feet no micro-organisms at all can as a rule be found. The relation of this to our water-supply and to the treatment of sewage is obviously one of extreme importance. As I have elsewhere stated, if water be taken from near the surface of soil in which there is a large quantity of organic matter present, there must necessarily be numerous aerobic putrefactive organisms in it, whilst surface drainage-water will invariably contain those organisms usually found in sewage and in excrement. If, however, water be taken directly from the deeper layers of soil, putrefactive organisms are usually absent, but a number of what are called water-organisms, non-spore-bearing harmless bacteria, are found.

If the water be kept perfectly undisturbed, unoxygenated, and at a comparatively high temperature, these water-organisms increase in number at a very great rate. It has been found, as a result of numerous bacteriological examinations by various observers, that if in a single cubic centimetre of any specimen of freshly-drawn water 200 bacteria are found at the first examination, by the end of twenty-four hours the number may have risen to 5,000, and the end of a second twenty-four hours to 20,000, and twenty-four hours later the multiplication has become so rapid and has gone so far that they are no longer countable. After a short time this multiplication ceases until the water is re-oxygenated. If, however, water be taken from a much deeper layer, micro-organisms are found to be almost, or entirely, absent, and not only micro-organisms, but organic matter, which has not been washed down to such a depth as that from which this water has been obtained. There are cases, however, of deep wells and springs, in which, although micro-organisms are practically absent, organic matter is still present in appreciable quantities. It is evident, then, that the superficial layers of earth act not only as mechanical, but also as biological filters. The water, with its contained organic matter, passes through the surface layers, in which bacteria can grow, down to those layers in which there are no organisms, the organisms not passing down with the water, first, because they are held back mechanically, the soil acting as a porous filter, by which even extremely minute solid particles are held back, but also because most of the bacteria being anaerobic cannot leave the surface with impunity, most of those that are carried down by the water dying off as their supply of oxygen is gradually removed; for, in conse-

quence of the rapid oxidation that is going on at the surface, very little free oxygen is left for the use of bacteria even in comparatively superficial layers. The few organisms that can persist develop the anaerobic faculty and utilize the small quantity of oxidized material that has not been converted into inorganic matter and used up by growing plants. This amount is small because the reduction of the small quantity that remains after the plants are satisfied is soon completed, and bacteria can no longer obtain any material for their nutrition. When these conditions are borne in mind, it becomes evident that much valuable information as to the character of any water and its suitability for domestic use may be derived from a bacteriological examination, it being understood that the mere number of organisms can convey little accurate information except in those cases where it is examined at once, and even in such cases the information obtained is not of prime importance. Quite recently you have had a most animated discussion on the action of biological filters. So important is this question, and such a prominent part is it destined to play in the future of sewage disposal, that the discussion extended, I believe, over three nights after the Paper had been read, and much still remains to be said on this most important question. I should like at this stage to indicate that what takes place in the breaking down of organic matter in nature may also take place, under certain conditions, in artificially-prepared filters. The main factors in the process are essentially the same as those already described. In the process it is necessary (1) to get all solid matter into solution; (2) to supply as large a quantity of oxygen in as short a time as possible to this organic matter; (3) to attack the organic matter in solution by means of micro-organisms and to so break it up that the various elements of which this complex material is composed may be thrown into an unstable or nascent condition so that the oxygen present may have an opportunity of entering into combination and of forming what are called oxidized substances. It is evident from what we know of putrefactive processes that these changes may take place in two perfectly different ways. In the one case we have the oxidation taking place directly, all the nascent substances being satisfied by the oxygen of the air and the splitting up of the organic matter being carried on by aerobic organisms. In such a process of oxidation which takes place in porous soil well supplied with air and moisture, and also in water which is from time to time well saturated with oxygen, it will be found that little or no putrefactive odour is developed. The

marsh gas, the sulphuretted hydrogen and other similar substances as they are set free rapidly combine with oxygen to form sulphuric acid, carbonic acid and water, and the nitrogenous substances in a similar fashion combining to form nitrous and nitric acids. In the soil these acids combine with the various basic substances, lime, magnesia and the like, are thus rapidly removed and the way is left clear for the formation of fresh batches of the same substances. In anaerobic putrefaction, on the other hand, the process does not go in this unobtrusive fashion, the anaerobic organisms having as it were to wrest their oxygen from the organic molecules because there is no free oxygen present, set up a much greater disturbance and the products of the decomposition such as sulphuretted hydrogen, marsh gas and ammonia, are thrown off in an unoxidized condition and in the free form (*i.e.*, they are no longer in a nascent condition) they remain comparatively stable, and give rise to the putrefactive odours so characteristic of rapid anaerobic putrefaction.

What an important part micro-organisms play in promoting the growth of plants has in recent years received most striking proof. Certain organisms have recently been described, which appear to have the power of fixing the nitrogen of the air, and of conveying it to the roots of the plants, near which they are carrying on their work. How far this has been developed you will understand when I tell you that cultures of these organisms are now made for sale. These kept in closed bottles may be sent to all parts of the world. Then mixed with water and thrown over the soil they immediately begin to do their work, and, taking nitrogen from the air, which lends valuable assistance to that from the soil, they enable the plant, especially those requiring large quantities of nitrogen for their full growth and development, to grow both more rapidly and more luxuriantly than they could if unaided by this supplementary store of nitrogen. When three of these leguminous plants are grown simultaneously, one in sterile soil and watered with sterile water, a second in ordinary soil and watered with spring or rain water, and the third in soil and water to which these organisms have been added, a most striking difference in the rapidity and luxuriance of the growth of the three plants is observed. The first is a weak delicate plant which grows slowly and soon loses vitality. The second grows as do ordinary plants or seedlings of the same species. Whilst the third grows rapidly, has most luxuriant foliage, and often grows to three or four times the size of the normal plant in the same time, thus affording ample evidence of the great activity of these organisms as nitrogen carriers.

In relation to disease, the part that bacteria play as ultimate causal factors is one of prime importance. If bacteriology had done nothing more for us than draw our attention to the concrete specific bacillus as a cause of cholera, for example, so as to allow us to concentrate our attention on special preventive measures, instead of leaving us to wander in the wilderness of "conditions of soil," of "atmospheric influences," of "epidemic waves," and the like, its value would have been amply demonstrated. Do not for a moment misunderstand me and assume that I undervalue in the slightest degree the careful observations that have been made by deservedly eminent epidemiologists, whose work has a value which can only be enhanced by what can be added to it by the bacteriologist. I do wish, however, to point out that since Koch's investigations have been accepted as trustworthy and as the basis on which preventive measures may be founded, we in this country, at any rate, through our admirably constituted Local Government Board, with its organised staff of medical officers and inspectors, have been able, without resorting to strict quarantine, to deal with the specific cases of cholera that have been brought to, or have appeared on, our shores in a fashion that even a few years ago could never have been anticipated. I further wish to insist that, whatever great predisposing causes may be at work, whatever subsoil, atmospheric, or other conditions may be necessary for the production of an epidemic disease in our midst, we have ample evidence that without the introduction of a special and specific causal agent from some centre in which such disease is rife, we have never had an outbreak of the special form of disease. Of course, in every outbreak there are men who come forward to show, on the one hand, that only Koch has right on his side, and, on the other, that all wisdom lies in Pettenkoffer's theories; but few seem to act, as if, whatever they may believe, the observations of both men should receive serious consideration. Seasonal variations, temperature, drainage, rise and fall of ground water, all play an important part in determining the conditions of growth of bacteria; whilst, on the other hand, bad ventilation and filth, famine and illness, all predispose patients to attack. But without the specific organisms that actually set up infective diseases, no infective diseases will occur. Celsus, the great physician, taught that predisposing causes alone were insufficient to set up disease; whilst, on the other hand, exciting causes by themselves were powerless to act. But when they came to act in combination, he maintained that they were both sure and far-reaching in the production of disease. The same applies to-day, whether we have

to deal with diphtheria, typhoid fever, cholera, or tuberculosis. Pettenkoffer deals with predisposing causes and conditions, Koch with exciting factors—bacteria. When disease has not yet come amongst us, let us follow Pettenkoffer; but when it is in our midst, or in our immediate vicinity, Pasteur, Koch and Lister are immediately advanced to the position of more trustworthy guides and leaders.

The first disease in which undoubted evidence was obtained of the agency of bacteria, anthrax or splenic fever, was very fully investigated by Davaine, but his investigations stopped short of the complete proof of the connection between cause and effect. Still, his work was the first of the kind, and undoubtedly indicated the lines on which Pasteur afterwards commenced and carried out many of his investigations. Then Koch, and later Pasteur, working with different methods, were able to prove that the anthrax bacillus and splenic fever stood in relation to one another as cause and effect. It was also found that the organism might be so modified by the action of heat and certain chemicals that when introduced into the tissues of an animal susceptible to anthrax a mild form of the disease was set up. This animal was then found to be much more resistant to the action of the virulent organism. Somewhat similar observations had already been made in connection with fowl cholera, and the one confirming the other, we for the first time had scientific proof of the accuracy of Jenner's theory of vaccination. Following rapidly on the discovery of micro-organisms in anthrax and fowl cholera came other specific germs, the tubercle bacillus, cholera and typhoid bacilli, the organisms that give rise to the formation of pus or matter in abscesses, the tetanus bacillus, the pneumonia bacillus, the diphtheria bacillus, and so on with a list of considerable length, one of the most recent additions being the bacillus of plague, an organism that belongs to a group that had already been recognized by Pasteur, and also by workers in Germany—the group setting up hæmorrhagic septicæmias or blood-poisonings. I show some of these organisms on the screen as a matter of interest, but we cannot at present attempt to enter into any detailed history of the steps by which these organisms were proved to be etiologically connected with the various diseases mentioned. I must, however, say a few words about the various theories of protective and curative inoculations and injections that have been advanced in recent years. We have already mentioned that when the anthrax organism is modified by heat and is then injected into an animal, it sets up a form of the disease so mild that the animal is not killed, whilst as the result

of this mild attack, it is to a certain extent protected against subsequent attacks of the same disease. Then, too, it is of course well known that, taking diphtheria as an example, patients often recover from attacks of specific infective diseases, and as they are extremely weak at the end of the disease, much more so than at the beginning, some explanation was necessary to account for the dying off of the organisms and for the recovery of the patient. Numerous explanations were given, but for a long time no one of them was at all satisfactory. Ultimately it was observed that in the blood of those patients who had recovered from the disease was a substance which, injected into other animals, protected them against infection, and it has been found that this protective substance is formed during the course not only of diphtheria but of tetanus, of typhoid fever, and of plague, and that it can be produced at will by injecting animals with doses of bacteria, gradually increasing in strength and quantity until a high protective potency of the serum is obtained. Even the introduction of the actual bacteria is not necessary in order that this result may be obtained, as the products of bacteria, grown outside the body and then injected into animals, will bring about the formation of a similar material; that is, the poison formed by diphtheria bacilli when injected alone, *i.e.*, without the bacilli themselves, into an animal will lead to the production of the protective substance in the blood of the infected animal, and this in such large quantities, that the blood withdrawn and injected into a second animal protects this second animal against an attack of diphtheria. This is the theory of toxins and antitoxins as applied to disease, and as based on the antitoxic treatment of diphtheria which has already done so much to diminish the diphtheria death-rate in our large cities. There can be no doubt, however, that this matter is still in its infancy, and that within the next few years great advances will have been made in the treatment of micro-organismal diseases and of other diseases of a similar nature; and it is only within the last few days that Koch has been able to devise a method of treatment of the cattle-plague or rinderpest — a disease which, in Africa, where the inhabitants rely so much upon cattle both for their support and means of travelling, has had most disastrous consequences—which may be the means of preserving, or rather restoring, the prosperity of a great tract of country. It must be remembered that, although he has not yet found the organism which is the cause of the disease, the methods he has employed are entirely the outcome of bacteriological investigations. In the treatment of these specific infective

diseases, two perfectly distinct methods have been employed; the first of these, as used in cholera, in hydrophobia and in anthrax, is the protection of the animal by the induction of a mild attack of the disease, or by introducing dead or partially devitalised organisms into the system, the animal forming its own antitoxic substances. In the second method we have the antitoxic substances produced vicariously and as in a test-tube, so that the patient to be treated, not having to wait for the modification of the whole of his antitoxin producing-cells, as the antitoxin is introduced ready made, gets the benefit of the gain of much valuable time, and so has a greater chance of recovery. The one method of treatment anticipates the disease, the other cures it; but both may be useful, and, in all probability, one may be applied with greater prospects of success in one, the other in other forms of disease.

It is remarkable how the study of bacteria has emphasized the accuracy of the earlier observations of workers at sanitary science, and how the observations on the effect of light and air, moisture and temperature upon bacteria have confirmed what had already been arrived at by empirical observation. Let us take the action of light, for instance. It has long been known that the effect of light was to help to purify places in which fungi had taken up their abode, and that those houses in which the light was cut off were always more subject to infective diseases than well-lighted apartments. Of course it was assumed that where light could not get in air was kept out, and consequently light as a factor was somewhat minimized. The experiments of Marshall Ward and Cartwright Wood, following a long series of others on the same lines, give definite proof of the importance of light as a germicidal agent. Adopting a new method, they exposed spores to active sunlight, and then placed them on a thin layer of agar-agar, or Japanese isinglass, to which had been added a quantity of nutrient broth. Taking other spores and treating them in the same way, with the exception that they were not exposed to light, the results were found to be very distinct; those that had been exposed to light were unable to develop into colonies, or at least were very much retarded in their growth, whilst those that had not been exposed developed freely and luxuriantly. These experiments, following similar, but not identical, experiments carried out by Buchner with the germs of typhoid fever, proved beyond possibility of cavil the action of light on pathogenic bacteria and spores. This factor of light, although too much importance cannot be assigned to it in its "surface" action, may sometimes be over-

estimated as an agent in the purification of rivers; for Wood, continuing this work, found, as was afterwards observed by Frankland, that the passage of the actinic rays is materially interfered with by very thin layers of water, even when comparatively clear; whilst in water that is in the least muddy, the actinic rays cannot penetrate at all, at least not with sufficient power to affect micro-organisms.

Coming now to the question of fresh air, it is recognised that the main action of fresh air in enabling patients to resist disease, is in the effect that it has on oxidation of the blood and so in the improvement of the nutrition of the body. It has a still further effect in that it brings about the steady oxidation of the products of bacteria. At the same time where plenty of fresh air is present, anaerobic organisms, which as we have seen are those which give rise to foul smells and to unstable and therefore to active products, cannot maintain a very active existence, and even where they are enabled to grow and give rise to foul-smelling gases and irritant substances, such products are much more easily oxidised into comparatively innocuous substances when plenty of fresh air and oxygen can be obtained. It is only necessary to indicate the nature of these processes for you to understand the importance of light and fresh air in the purification of our dwellings.

In following out the study of bacteria, it is interesting to observe how intimately the advances in our knowledge of these minute organisms have been associated with the question of "spontaneous generation." Within a century of the discovery of bacteria, little was done beyond the finding of these organisms in almost every kind of organic matter, in the soil, in vegetable infusions and in water; then the theory of spontaneous generation again came prominently forward and was made the battle-ground on which the development of bacteria was fought out. These minute lowly-organised germs were looked upon as harbouring the beginnings of life. They, indeed, were supposed to be the result of the running together of certain chemical elements which, having assumed a certain form, became endowed with life. This fascinating theory owed much to countrymen of our own, Dr. Needham, and later Dr. Bastian, who threw into its proof a great amount of patient investigation and ingenious reasoning. The Abbé Spallanzani threw doubt on all Needham's experiments and results by showing that if his infusions were first boiled and then, while hot, firmly sealed, no organisms ever made their appearance in the fluid until the seal was broken and air (and with it particles of dust with their accom-

panying bacteria) allowed again to come in contact with the boiled infusion when a luxuriant growth took place, the fluid becoming turbid and often foul smelling. Numerous explanations of this fact were attempted and experiments of all kinds were devised to prove that boiled or burnt air would not allow of the growth of organisms; all of them in turn were met with disproof by those who did not believe in spontaneous generation. The final blow to spontaneous generation was really given by Schröder and Van Dusch, who performed a series of experiments by means of which they were able to demonstrate that putrescible solutions contained in flasks, plugged with clean cotton wool and then boiled for some time, would remain perfectly clear and sterile as long as the cotton wool was not removed or damped. Air could pass through the cotton wool, but all solid particles were kept back, and as long as this was the case, air, of course not burnt or boiled in this instance, came in contact with the fluid, but without its contained solid and living particles it gave rise to no putrefaction. Then came the demonstration of the fact that when blood or milk, both of them highly putrescible substances, were taken with such precautions that no particles from the air were allowed to come in contact with them, they could be kept perfectly sweet for an indefinite period by simply placing them in these flasks previously sterilised by heat and plugged with sterile or heated cotton wadding, so arranged that there was free access of fresh air to the surface of the fluid, but a straining out of all solid particles.

Sixty years ago, the proof that the yeast plant was a living organism, and the cause of the process of fermentation, was almost complete, whilst only a year later the germs of the silkworm disease were observed; but it was not until more than twenty years later that Pasteur was able to point out the full import of these discoveries. Pasteur's work on fermentation and on disease, his experiments on attenuation of organisms, on protective inoculation and on curative injection for hydrophobia, have already been referred to and are so well known that it is unnecessary to do more than mention them. Dr. Koch was able, by his new methods of separating organisms by means of solidifying media, to go beyond Pasteur in isolating the anthrax bacillus and in proving to absolute demonstration the relation of the anthrax bacillus to splenic fever. His ingenious methods of cultivating organisms, of staining them in tissues and of separating the different species, created a new era in bacteriology, just as much as did his postulates in making a new starting-point for the study of the causation or etiology of disease.

In this country we owe to Lord Lister the great advances that have been made in the treatment of wounds, by which thousands of lives are yearly preserved, advances which date from his study of bacteria and bacteriology. Antiseptic surgery, like the antitoxic treatment of diphtheria, is based entirely upon the early researches on bacteriology, and its development has followed most closely the advances made in that subject. As yet no one can say that we have reached even a resting-stage, and it behoves all those who desire to see advances made in the treatment and prevention of disease, whether in the department of protection and cure, with which medicine is specially concerned, or in the preventive department, with which you as Civil Engineers have to deal, to continue to follow closely every new fact and every fresh theory arising out of new observations, in order that bacteria and the forces with which they are endowed may be made our well-disciplined servants, instead of being allowed to waste their energies as our uncontrolled and uncontrollable masters.

Mr. J. WOLFE BARRY, C.B., President, said it was stated in the Charter of the Institution that the object of the profession of Civil Engineers was to direct the great forces of nature to the use and convenience of man. They had just listened to a most instructive and suggestive discourse, teaching them how much might be done in directing the forces of what perhaps might be called the infinitely little, not only towards the use and convenience of man, but in the direction of his preservation from disease and disaster. The subject which had been dealt with must appeal to many of them as one of peculiar interest, particularly to that branch of the profession that devoted itself to water-supply and sanitary matters. But apart from any special devotion to such subjects, the questions that had been dealt with by Dr. Woodhead were of surpassing interest to everyone, whether he was an engineer or merely concerned in them as a member of humanity. He felt sure the members would think that the Council had not acted unwisely in asking a gentleman belonging to a profession outside their own to enlighten them in the discoveries of modern science, and that they would all reap the greatest benefit from the interesting and suggestive lecture that had been delivered. They were also grateful to Dr. Woodhead for illustrating his Paper with his beautiful photographic slides, which probably few of them had ever seen before, and on which they would always look back with very pleasant recollections of

the greatest interest. He begged to propose that the members should give a hearty vote of thanks to Dr. Woodhead for his kindness in coming to deliver the lecture to which they had all listened with so much pleasure.

Mr. W. H. Preece, C.B., Vice-President, said that after such an expression of opinion from the Chair, he should have scarcely thought it necessary that anyone should be called upon to second the resolution, but he responded to the call with extreme pleasure. If it were the wicked will of the Institution to inaugurate a system of examinations, and if in the near future it should be considered desirable that the members of the Council should pass through such examination, he should desire that the subject on which he was examined should be that of bacteriology, for he felt, owing to the skill of the lecturer, and the admirable character of the illustrations, that he could himself now pose as an authority on that subject. They had been taught that—

"Little fleas have little fleas
Upon their legs to bite 'em;
And lesser fleas have lesser fleas,
And so *ad infinitum*."

They had now absolutely become acquainted with those diminutive creatures, and almost began to feel a kind of affection for them; for not only were they told that they were doing an infinite amount of mischief, but they had been given to understand that in their bodies and in other places a species of prize fight was going on, and that one bacterium was able to demolish the other. He was sure that all had been delighted with the lecture, and that they would be pleased if next week it could be repeated for the benefit of others. In seconding the resolution he felt that he should only be expressing the opinion of those present; and that by means of the printed lecture information of a most valuable kind would be put in the hands of all the members of the Institution of Civil Engineers.

The motion was thereupon carried by acclamation.

Dr. Woodhead said he desired to thank the members for the very lenient view they had taken of his desultory remarks. He had been disappointed that he had not been able to lay before the members in a rather more definite, and perhaps more condensed fashion some of the points that he had wished to bring forward. He had been obliged to cut out much of what he had desired to say, but that was due rather to an error of judgment than any want of a desire to make the lecture thoroughly interesting.

ENGINEERING CONFERENCE.

MAY, 1897.

The Conference was opened on the 25th of May at the Westminster Town Hall, when Mr. J. Wolfe Barry, C.B., the President of the Institution, delivered a brief address to a combined meeting of the Sections.

After expressing the gratification of the Council that the co-operation of upwards of eight hundred of the members was known to have been secured, the President made some explanatory remarks on this new departure in the work of the Institution. A principal object in organizing the gathering had been to afford those country members who were unable to attend the ordinary weekly meetings of the session, but who were often in London towards the end of May, an opportunity of participating in the consideration of, and of exchanging views on, various questions of professional interest. A Committee of the members had been invited to select topics to be considered. These subjects would be introduced in brief "Notes," which would be debated in such a way as to allow some elasticity in the mode of considering them. To this end a less formal and more conversational style of discussion would be admitted than was advisable at the Ordinary Meetings; and it was hoped that this would encourage many who, from want of opportunity or from natural diffidence, often failed to impart to their fellow-members the results of valuable experience.

To be useful, a gathering of this nature must work by sections, and specializing became a necessity. At the same time there must, no doubt, be a considerable amount of overlapping, and persons would of course be able to attend meetings at which subjects which interested them were discussed, whether those subjects were or were not those to which they specially devoted their career.

The Sections into which the Conference had been divided were:—

I. Railways: Chairman, Sir Benjamin Baker; II. Harbours,

Docks and Canals: Chairman, Mr. Harrison Hayter; III. Machinery and the Transmission of Power: Chairman, Sir Frederick Bramwell; IV. Mining and Metallurgy: Chairman, Mr. T. Forster Brown; V. Shipbuilding: Chairman, Sir William White; VI. Waterworks, Sewerage and Gasworks: Chairman, Mr. Mansergh; VII. Applications of Electricity: Chairman, Mr. W. H. Preece.

A secondary, but still important object had been the organization of a series of visits to works of interest in and around London, and here the President ventured to convey by anticipation the warm thanks of the whole Institution to those public bodies, firms and individuals who had thrown open for inspection the many interesting undertakings which would be comprised in the visits arranged for.

The President hoped and believed that the Conference would prove such a success that it would be held annually. It would be well, however, that it should be understood that (as far as the views of the present Council were concerned) there was no idea of making the Conference other than a Metropolitan gathering, nor of competing or interfering with the arrangements of the various Societies which from time to time met at various towns in the kingdom. London was the home of the Institution, associated not only with so much of present interest, but also with the important memories of the past, with Telford, Walker, the Rennies, the Stephensons, the Brunels, and others who had gone before and who had laboured hard to establish on a firm foundation the honour and reputation of their great Institution.

Established in 1818, and more fully organized in 1820 when Telford accepted the Presidency, that Institution was at first, by reason of the faulty means of intercommunication in those days, mainly a society of Londoners. Now, however, of the seven thousand persons, in round numbers, borne on the roll of the Institution, five thousand were in the United Kingdom and two thousand were abroad, while of the five thousand in the United Kingdom about two thousand were living or practising in London. In several of the great towns of the kingdom there were important and flourishing local associations, mainly established for the benefit of the Students of the Institution, but with other important functions. Again, there were associations such as the Liverpool Engineering Society, and others, which though under separate and distinct management, had always preserved most friendly relations towards the Institution, to which, in fact, most of their leading members belonged, thus securing throughout the kingdom a number of centres having common interests. It was

not the object of the Conference to diminish but to further and to consolidate those mutual relations between the Institution and the local associations, and the President concluded by welcoming in the name of the Council those who had accepted the invitation to take part in the proceedings.

At the meetings, which were held at the Westminster Town Hall and Guildhall, on the 25th, 26th, and 27th May, forty-eight Notes were read introducing subjects for debate, in the consideration of which upwards of two hundred speakers took part. The visits paid to engineering works numbered seventeen, and in respect of these two thousand tickets of admission were issued in response to the applications received from members and students.

A record of the matters presented for consideration at the meetings is contained in the Abstracts of Notes[1] given on the following pages, references being added to the various journals in which reports of the proceedings may be found.

[1] The full text of the Notes may be seen in the Institution Library.

ABSTRACTS OF NOTES INTRODUCING SUBJECTS FOR DISCUSSION.

SECTION I.—RAILWAYS.

25 MAY, 1897.—*No. 1.*

"Rails and Permanent Way."[1]

By HAROLD COPPERTHWAITE, M. Inst. C.E.

The Author, after drawing attention to the ideal permanent way and to the necessity for good ballast, discussed in some detail sleepers and rails. On fairly busy lines in Yorkshire the average life of sleepers, twelve years to fifteen years, was not so long as that of steel rails. Cast-iron, wrought-iron, and steel had been tried, but the Author considered that the general results were disappointing, especially on lines where ashes were used for ballast. Australian Jarrah and Karri woods, the weight of the latter being double that of common creosoted sleepers, were now being tried in this country. The bull-headed steel rail, weighing 65 lbs. to 70 lbs. per yard, supported on sleepers 2 feet 10 inches apart, was generally admitted to be strong enough to carry the loads at present running on any public railway in these islands. Allowing ½ lb. per yard to be the annual loss on fairly busy lines, the Author recommended an 80-lb. rail, which would last twenty years. He believed, however, that molecular changes, due to the weight and velocity of passing loads and to the condition of the road-bed, generally modified the structure of the rail and entirely destroyed its usefulness as a load-carrier; but he pointed out that on many railways this loss was met by the use of partly-worn rails in sidings and station yards.

[1] *The Engineer*, vol. lxxxiii. p. 533; *Engineering*, vol. lxiii. pp. 706 and 727.

No. 2.

"Permanent Way."[1]

By Francis William Webb, M. Inst. C.E.

In 1877, owing to the necessity for strengthening rail-joints, the Author worked out by experiment the deep fish-plate, which was now in general use on the London and North Western system, in conjunction with the bull-headed section of rail, the latter having replaced the double-headed section and done away with the objectionable practice of reversing rails. At the same time the Author suggested the adoption of galvanized screwed spikes, using a creosoted wooden ferrule in the old treenail hole, tapering the neck of the screw for the last inch-and-half of its length, and retaining the section of the chair-casting round the hole above the general level of the chair, thus protecting the wooden ferrule from the wet. He also recommended that a layer of felt should be placed between the chair and the sleeper, not so much on account of its elasticity, but to deaden the sound and principally to prevent abrasion by keeping out the wet and grit from the under side of the chair. A stronger joint was now required with the heavier rail about to be introduced, and the Author had suggested for experiment a joint in which the usual fish-plate holes through the rails were rendered unnecessary. The proportions of this joint had been determined by substituting lead for steel fish-plates above badly packed sleepers, and several such plates, showing the weak places, were exhibited.

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26 May, 1897.—*No. 1.*

"The Location and Cost of Working of Pioneer Railways."[2]

By R. Elliott Cooper, M. Inst. C.E.

The question of how to deal with railway communication in sparsely populated districts had taken different forms in various countries, and should be decided according to the ability of each country or district to produce a traffic which would pay immediately, while affording facility for increased expenditure in case

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[1] *The Engineer*, vol. lxxxiii. p. 533; *Engineering*, vol. lxiii. pp. 707 and 727.
[2] *The Engineer*, vol. lxxxiii. p. 539; *Engineering*, vol. lxiii. pp. 734 and 763.

the pioneer railway became a trunk line. As a rule the gauge should be the same as that of the general system in connection with which the proposed railway might at the outset, or at some future time, have to work. The importance of this was exemplified by the recent conversion in Cape Colony of about 53 miles of 4 feet 8½ inches gauge to the standard 3 feet 6 inches. The Author recommended surface lines for an undulating country, and to avoid continuous gradients in hilly districts the use of the rack, which in many cases might be afterwards replaced by a tunnel. He considered that 5-chain curves should not be exceeded on the 3-foot 6-inch gauge for large goods- or fast passenger-traffic. While avoiding costly structures, he thought all large works should be carefully located and constructed in a permanent manner and of sufficient strength to carry the heaviest rolling stock which the development of the traffic would necessitate. The locomotives might vary from 12 tons or 15 tons, as on the Italian agricultural railways, to about 80 tons including tender, now being used in other countries on the 3-foot 6-inch gauge. Where the weight of the engine did not exceed 30 tons to 35 tons, rails from 45 lbs. to 50 lbs. were ample while the line was in a pioneer state. The normal working expenses of this class of railway was usually from 45 to 75 per cent. of the gross receipts; but the Author referred to one case where a long continuance of bad weather raised this to 110 per cent.

No. 2.

"What is True and False Economy in Light Railway Construction?" [1]

By Arthur Cadlick Pain, M. Inst. C.E.

The Author pointed out that the smaller the volume of traffic to be carried into or out of a district, the smaller should be the capital expenditure, and that if railways were to be made in purely agricultural districts, the earning power would only reach about £4 to £7 per mile per week. Few of the public roads in the United Kingdom were suitable for the laying down of light railways, for they followed the routes of the old pack-saddle tracks or what were only footways or occupation roads. Even

[1] *The Engineer*, vol. lxxxiii. p. 539; *Engineering*, vol. lxiii. pp. 734 and 763.

in the construction of the turnpike roads but little skill was generally employed. To perpetuate the defects by laying light railways along them would be folly. Surface or contour railways had easier gradients, lighter engines and lower cost of maintenance than the somewhat shorter direct lines; and since the permanent way suitable for a line of easy gradients and a maximum weight of engines, say 9 tons on a pair of wheels, with rails of 50 lbs. per yard, would cost laid complete only £1,300 per mile, it was generally true economy to lengthen the line rather than shorten it. It was further true economy to provide plenty of stations or sidings on the route, so as to secure all the traffic in the district; to construct shelter for passengers and provision for receiving light goods; to lay in loops to the running lines at stations, so that trucks could be easily attached; to erect a strong timber fence where the line passed through grass land, and one of light steel wire through arable, down, wood or heath land. From 12 to 15 miles per hour should be the limit of speed to keep the cost of maintenance low. The Author thought the inconveniences of a break of gauge for a light railway had been overstated. It could be shown that in the difference between a 4-foot 8½-inch and a 3-foot gauge the saving in the cost of permanent way would be upwards of 40 per cent., and this saving might be increased in works if the country were at all heavy. It was unnecessary to buy land wide enough for two lines of way, or with few exceptions to provide a line of telegraph or telephone. It was unnecessary to provide cattle-pens, carriage-ramps, long or high platforms, goods sheds, carriage sheds, turn-tables, weigh-bridges, signal-boxes and interlocking of signals (except at junctions), until the requirements of the traffic when developed had shown them to be necessary.

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27 May, 1897.—*No. 1.*

"The Standardizing of Working Loads and Working Stresses for Railway Bridges."[1]

By John Mitchell Moncrieff, M. Inst. C.E.

After pointing out that in America bridges were designed to carry alternative train loads of two or more types, and that in

[1] *The Engineer*, vol. lxxxiii. p. 578; *Engineering*, vol. lxiii. pp. 771 and 795.

this country engines and rolling stock travelled upon other than their own system, the Author suggested the advisability of having standard working loads and stresses for general use in the United Kingdom. Writers differed widely as to the proper and sufficient loads to be provided for. Not only must the loads be considered, but also the accompanying dynamic effects due to loads being live and to the internal mechanism, the balance weights, pitching and rolling of the locomotive, the action of wind and centrifugal force and any possible future increase. The pitching and rolling of an engine with a short wheel base might have more effect than that of larger main line engines. It was pointed out that any particular bridge was tried most severely by some particular, not necessarily the maximum, train-speed. The Author further stated that although there was but little difference among engineers in their methods of computing loads on individual members in structures, yet the nature of the actual internal stresses induced in those members, depending upon the character and mode of imposition of the loads, must be clearly defined before any standardizing of working stresses could be laid down. The useful life of a structure depended on the internal stresses induced in it rather than upon the amounts of the loads imposed. The Author thought many cases of rivets working loose were due to the neglect of this principle. He drew attention to the lack of experimental data on the strength of full-size bridge members generally, and in conclusion stated that until such matters as these received fuller investigation, there would remain considerable difficulty in framing standard working stresses with any hope of their permanent or general acceptance.

No. 2.

"The Use of Small-Scale Experiments in some Engineering Problems."[1]

By Arnulph Mallock.

The object of small-scale experiments made on the behaviour of structures under load was to discover the relative strains and stresses which given displacements or forces applied at certain points produced at other points of the structure. In order to

[1] *Engineering*, vol. lxiii. pp. 771 and 794.

render the main features of any deformation visible to the eye and to bring it more readily under observation models were constructed of some elastic material such as india-rubber. The deformations of such a model built to one-tenth scale would exceed by ten times those which could be produced in the full sized structure made of steel. The Author exhibited a few examples of simple india-rubber structures on which a series of parallel black and red lines had been ruled, the former before and the latter after the application of the strains, thus showing at a glance the nature and magnitude of the deformations. The Author concluded with a reference to similar experiments on the size and rigidity of foundations.

SECTION II.—HARBOURS, DOCKS AND CANALS.

25 MAY, 1897.—*No. 1a.*

"Concrete in Relation to Marine Works."[1]

By JOHN KYLE, M. Inst. C.E.

The Author divided this subject into three heads; (i.) work in the yard; (ii.) mass-work under water, and (iii.) block-work under water. He advocated storing the cement 3 feet deep on a wooden floor, turning weekly and using after four weeks in store; the cement to have a residue of 7½ per cent. on a 2,500-mesh sieve, and three samples per 150 tons to be tested when two, four, and seven days old respectively. The stone and gravel should be free from fine dust, the sand not exceeding twice the volume of the cement, and the mixing—with either fresh or sea-water—being continued until a pasty condition was reached. Blocks in moulds should not be left unfinished over night, and blocks could be lifted eight days after making. He considered mass-work and bag-work under water to be uncertain, owing to probable disintegration and the want of bond between the several layers or the bags.

For block-work under water the blocks should be from four to eight weeks old, the size varying between 20 tons, as at Dover Harbour, and, say, 50 tons, and in favourable weather they could be laid at a rate of from thirty-five to fifty blocks per day. The bond should not be less than one-third the length of the block, and the laying was done either from timber staging or from an overhanging titan. Concrete walls could be founded on water-bearing beds if the water-pressure was kept off the concrete until it had well set.

[1] *The Engineer*, vol. lxxxiii. p. 533; *Engineering*, vol. lxiii. pp. 707 and 833; *The Contract Journal*, vol. xxxvi. pp. 1030 and 1031.

No. 1b.

"Concrete in Relation to Marine Works."[1]

By A. E. Carey, M. Inst. C.E.

For the construction of concrete, heavy close-grained stone—like granite—was preferable to the lighter and more porous kinds, while the sand used should be clean and sharp, broken material being preferable to sea-sand. The Author advocated as much irregularity as possible in size and shape of the stone used, but very large stones should be kept not less than 1 foot from the finished face to prevent their working loose. He preferred salt-water generally to fresh for mixing, and recommended 22 gallons per cubic yard. Cement of $3 \cdot 1$ specific gravity must necessarily be well burnt, and the finer the grinding the better the cement, 35 per cent. residue on a 180×180 mesh being about the finest at present obtainable. A heavily burnt cement, however, was not suitable for work at low temperatures. On large works, mixing by machine was almost universal and was more likely to give uniform results than hand-mixing.

The Author cited several cases of bag-work which had given very satisfactory results, especially for forming the foundation reef. The bags should be made 5 feet or 6 feet longer than the net length of the finished work, as there was always a tendency for them to break away at the ends when laid. At Sunderland the foundation was being formed with bags of 116 tons, 75 tons, and 52 tons, the upper work with blocks of 43 tons, and blocks in four courses with cross-walls at intervals, faced outside with granite and filled in between with mass concrete. At La Guaira the foundation was formed with bags of from 130 tons to 160 tons, while at Hastings mass concrete between frames was being used.

He considered, notwithstanding some cases of failure, often attributed to chemical decay in sea-water, that cement concrete, when properly made, was a perfectly reliable material for solid structures in the sea. It was almost the only material actually in use.

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[1] *Engineering*, vol. lxiii. pp. 707 and 834; *The Engineer*, vol. lxxxiii. p. 534; *The Contract Journal*, vol. xxxvi. pp. 1030 and 1031.

No. 2.

"The Arrangement of Docks: with Special Reference to the Formation and Maintenance of their Approaches."[1]

By H. F. Donaldson, M. Inst. C.E.

The Author classed docks generally under three types:—"Grouped Docks" as in the Mersey; "Extended Quay Docks" as the Royal Albert Docks, and "Fan-shaped or Jetty Docks" as at Tilbury and the Victoria Dock; but in all cases general design would depend on the site selected. One of the chief considerations was the provision of good and easy railway communication, enabling goods to be despatched with a minimum of delay; but proper warehouse accommodation must also be allowed for. The question of entrance channel was also important, as on its position and design depended to a great extent the cost of its future maintenance. The entrance channel should have ample bottom width at the lock entrance and widen out towards the fair-way; while both the channel and the lock should probably face down-stream if the locking and unlocking was mostly done during ebb tide, and up-stream if this took place during the flood. An entrance at right-angles to the fair-way was not recommended. The maintenance of the channel was rendered easier by giving the bottom a fall towards the fair-way, the silted material being removed by a current of water from the lock if possible, or by dredging. Where the deposits were comparatively fine, this latter method became much cheaper when it was possible to use the "blower" introduced by Mr. B. Tydeman for the Tilbury Dock. This consisted of two hydraulic pipes of armoured hose, connected at the lower ends by a metal rake having teeth and jets at intervals, through the latter of which water under pressure was ejected, the pipe or rake being towed along the channel bottom behind a tug, which supplied it with the necessary water. The rake-teeth and jets of water stirred up the sediment, which was carried away by the same current that had deposited it. The pressure of water was generally from 35 lbs. to 80 lbs. per square inch, but 150 lbs. per square inch might be necessary when the deposits had been left some time undisturbed.

[1] *Engineering*, vol. lxiii. p. 710; *The Contract Journal*, vol. xxxvi. p. 1031.

27 May, 1897.—*No. 1a.*

"The Value and Scope of Inland Navigation."[1]

By E. D. Marten, M.A., M. Inst. C.E.

There were still many canals in England which, although in their original primitive condition, could compete successfully with railways in the carriage of heavy goods. These canals could only admit a boat 70 feet long and 7 feet beam, carrying not more than 35 tons, and were unadapted for steam propulsion. If such canals were improved and developed the cost of carriage for heavy goods might be reduced below anything at present deemed possible. How could this best be done?

In many cases improvements up to a certain limit could be made at a moderate outlay, while beyond this the cost became prohibitive, or very great. This was the case with the waterway between Bristol and South Staffordshire, where, out of 103 miles, 78 miles would, with only trifling alterations, admit barges of 225 tons capacity, while only the usual small boats could pass over the remaining 25 miles. The Author here recommended an outlay of £360,000 on the last 25 miles, thus giving this portion the same capacity as the rest, and this sum included the reduction of the ponds from thirty-one to eleven; inclined planes in places to replace groups of locks; and straight cuts, reducing the distance 2½ miles, instead of the more awkward curves. The dimensions of the canal when improved were to be 60 feet wide at top, 40 feet at bottom, and 7 feet deep. The locks were to be capable of passing vessels 85 feet long, 19½ feet beam, and drawing 6½ feet; thus sea-worthy steamers of 150 tons capacity could run between Wolverhampton and London or other ports. The Author considered that if only reasonable interest on capital were demanded, there should be no difficulty in the formation of a trust to carry out such improvements, whereby the carriage of heavy goods between Wolverhampton and the ship-side at London could be reduced to half that now charged by the railway companies.

[1] *Engineering*, vol. lxiii. pp. 771 and 796.

No. 1b.

"The Value and Scope of Inland Navigation." [1]

By Lionel Bury Wells, M. Inst. C.E.

The Author pointed out the absence of trustworthy statistics in regard to this subject. Sixty years ago the rate of carriage on canals appeared to have been 3*d.* for perishable goods and 2½*d.* for imperishable goods per ton per mile, but it was difficult to say what it was now. A canal had an advantage over a railway in point of cheapness of construction. The Bridgewater canal cost £5,000 per mile, and if another £5,000 were allowed for improvements, this would only give a cost of £10,000 per mile, against about £47,000 for a first-class railway. Maintenance of works and plant was also less on a canal, while the staff required per ton per mile was about the same. In facility for loading and unloading, the canal had the advantage, although in speed the railway was superior; but this superiority could be much reduced if regularity were insured on the canal by proper organization.

In the United States and France canals were being developed and improved, and 6,000,000 tons of goods entered Paris alone by canal against 15,000,000 tons by rail. In 1892 French canals carried 26,000,000 tons; English, in 1886, carried 34,375,000 tons. The Author gave statistics showing how small was the proportion of the total traffic carried by canals in England compared with other countries; and, while pointing out that, although railways had greatly developed, the state of the canals had hardly altered during this century, he considered that the only possible reduction of rates for the internal transport of goods was by improving and organizing the canal systems.

No. 1c.

"The Value and Scope of Inland Navigation." [2]

By John Arthur Saner, M. Inst. C.E.

The Author considered that the first step in the development of inland waterways was to persuade railway companies that a proper

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[1] *Engineering*, vol. lxiii. pp. 771 and 796.

[2] *Ibid*, vol. lxiii. pp. 771 and 797.

system of canals would be an auxiliary to them and not a competitor in the carriage of goods and minerals. The disadvantages of canals were: slower carriage, and a difficulty of increasing the present speed owing to the locks; probable disorganization by frosts and floods; difficulty of arranging levels to suit existing works, and the necessity for discharging by crane or power. The first disadvantage he considered small, and it could be reduced by substituting hydraulic lifts for groups of locks. The disorganization by floods and frosts would be diminished by an increase in section of the canals and their adaptation to steam propulsion, while the difficulties of discharge would be minimized by the adoption of suitable machinery, as on the Weaver.

The advantages of canals over railways were the following: goods could be more easily carried in bulk; the boats could load and unload at any point along the canal; there was less likelihood of breakage of goods, and the cost of repairs and maintenance of way and plant was less. The Author advocated the use of "Omnibus" boats for small quantities of goods, and the increase of the canals to a width of 40 feet at bottom, 72 feet at top, and a depth of 8 feet, admitting vessels of 210 tons displacement, the locks being made to take two or four such boats. By development on such lines as these, he considered that the value and scope of usefulness of canals could be much enhanced.

No. 2a.

"Comparison of Dredging and Training Works as Means for the Improvement of Rivers."[1]

By Alexander Farquharson Fowler, Assoc. M. Inst. C.E.

As a general rule training works were used to give stability to the position of the channel of a river, while deepening was done by dredging. In some cases, however, extra depth could be obtained by training walls. Rivers with tidal estuaries presented many difficulties to forming and maintaining channels, the disturbing influences being: scouring action of the tides, fretting action of the waves, and transporting action of the wind. Training walls to deepen the channel should be carried out into deep water, to avoid shoaling at their ends. Where there was a sandy bottom

[1] *Engineering*, vol. lxiii. pp. 774 and 796.

with facilities for depositing the dredged material, large quantities could be very cheaply removed by pumping, while comparatively small training works would often effectually maintain a channel when once formed.

No. 2b.

"Comparison of Dredging and Training Works as Means for the Improvement of Rivers." [1]

By IVAN COLLINGWOOD BARLING, Assoc. M. Inst. C.E.

The improvement of non-tidal rivers was comparatively simple, the current being only in one direction, and the work being generally done by dredging, supplemented by a judicious regulation of the water-way. In dealing with tidal estuaries the following considerations must be borne in mind: a channel was required of a given width and depth throughout, unnecessary width and depth in parts being sometimes even detrimental. Land reclamation, if aimed at, should be a secondary object; and where training-walls were used in a channel, care must be taken that the river as a whole would not be injuriously affected by the shallows which would form behind such walls. In addition to making the ebb and flood tides follow the same channel, the latter should be made as short as possible.

With hard bottoms such as clay, dredging only would probably be effective; but with a soft alluvial bed, training works afforded almost the only satisfactory means of improvement. With a moderately hard bed, as sand, training-walls and dredging might be employed, and important results could be effected with the suction dredger in such material; but unless the dredging was done at the outfall of the river, its injudicious use might cause serious injury to other parts of the channel. Training-walls were usually only carried to about half-tide level, but the Author did not think there was any advantage, except as regarded initial cost, in not carrying them up to high-water level.

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[1] *Engineering*, vol. lxiii. pp. 774 and 796.

No. 3.

"On Automatic Dredging of Rivers and River-Bars."[1]

By the Hon. RICHARD CLERE PARSONS, M.A., M. Inst. C.E.

Having had to consider the question of deepening two large rivers with alluvial beds, the Author determined to ascertain to what extent the river current could be diverted towards the bottom, so as to produce scour. He therefore constructed a model of a portion of the Rio Paraná, with which he was well acquainted, 20 feet long, on a horizontal scale of $\frac{1}{5000}$, and a vertical scale of $\frac{1}{450}$. The banks were formed of concrete, and the islands and sandbanks of putty, and a current, carrying a large amount of fine silt in suspension, was caused to flow down it. The shallows formed were found to correspond with those in the actual river, and the effect was then tried of mooring a model barge across the channel with a curtain suspended from it and lowered into the stream until the scour along the bottom was sufficient to remove the silted matter. The barge and curtain were then allowed to slowly drift down stream, which had the effect of scouring out a channel the width of the curtain. The increase in velocity of the current along the bottom was approximately 50 per cent., and apparently little water flowed round the ends of the curtain. From the experiments the Author concluded that, with an apparatus of this nature, it would be possible to control the course of a large river, to cause the silt in a tidal river to be carried, during the ebb, towards the sea, or to increase the depth of water across a sand-bar—these results being obtained by the expenditure of only such power as would be necessary to manœuvre the vessel carrying the curtain.

[1] *Engineering*, vol. lxiii. p. 774.

Section III.—MACHINERY AND TRANSMISSION OF POWER.

25 May, 1897.—*No. 1.*

"The Transmission of Power by Electricity."[1]

By William Henry Preece, C.B., F.R.S., Vice-President Inst. C.E.

The utilization of the waste energies of nature was the highest function of the engineer. Millions upon millions of units of energy were being expended on changing river-beds, and on carving the surface of the earth into hills and valleys. Their transport to centres of civilization meant not only the permanence of the face of nature, but the exercise of true economy. There were three effective modes of transmitting power—by electricity, by water and by air. Each method of transmission was limited by the strength of materials, the loss of energy, the heat generated, and the physical difficulties overcome, the dangers to person and property, the capital expenditure and the cost of transmission and delivery. It was the peculiarity and value of electricity as the medium of transmission, that the energy wasted on the line could be kept at a constant quantity independent of its length, but the cost of maintenance must increase with its length. Hence the maintenance of the line and the capital expenditure on it must be the main items. The waste by heating was so far reduced by using high pressures that if it were practicable to exceed the present maximum (10,000 volts in England and Germany, and 6,000 volts in the United States), it would be possible to transmit power by electricity through distances of 200 miles so as to compete favourably with steam. But with the present price of coal in this country, and with practical pressures, the radius of economical delivery did not exceed 40 miles.

It would certainly be possible to utilize the waste energy of the magnificent cataracts at Merawi and Wady Halfa in Cairo, or its neighbourhood, the only question being how the cost would

[1] *The Engineer*, vol. lxxxiii. pp. 534 and 535; *Engineering*, vol. lxiii. pp. 710 and 727; *The Electrician*, vol. xxxix. pp. 147 and 149; *The Electrical Engineer*, vol. xix. pp. 679 and 681; *The Electrical Review*, vol. xl. pp. 735 and 794; *The Contract Journal*, vol. xxxvi. pp. 1027 and 1029; *The Journal of Gas Lighting*, vol. lxix. p. 1239.

compare with that of fuel from England. There were many instances of the electrical transmission of power to distances up to 36 miles in the United States and Canada, and in Italy, at Tivoli, 50,000 gallons of water per minute falling 160 feet, and yielding the equivalent of 2,400 HP., were made to furnish 1,196 HP. in Rome. In England at Foyers, Keswick, Windermere, and Lynton, electricity was generated by water-power, but was not transmitted to any great distance. At Worcester about one-third of the power required for lighting the town was generated by a 10-foot fall on the River Teme, some two miles away, at a net cost of less than 0·8*d.* per unit.

To the consumer electricity presented many advantages as a means of distributing power. It was easy of application, reliable, safe and clean. It minimized the loss of power in the shafting, which was found by Mr. C. H. Benjamin, of Cleveland, to be between 50 per cent. and 80 per cent. of the power developed. It was also economical, being always ready for use, and used only when wanted. The efficiencies of good modern dynamos and motors ranged frequently from 94 per cent. to 96 per cent. Hitherto high prices, ignorance and fear had kept it in the background, but it was rapidly coming to the front.

No. 2.

"The Transmission of Power by Water." [1]

By Edward Bayzand Ellington, M. Inst. C.E.

The distinctive feature of hydraulic transmission was that the medium was an inelastic fluid. The velocity should be kept low to minimize shocks and friction. The main engines were run at constant load, and at a speed varying with the consumption. The efficiency was as follows:—

	Per cent.
Loss at central station	15
„ in transmission	5
„ in use	5
Net power utilized	75
Total	100

[1] *The Engineer*, vol. lxxxiii. p. 535; *Engineering*, vol. lxiii. pp. 710 and 728; *The Electrician*, vol. xxxix. pp. 148 and 149; *The Electrical Engineer*, vol. xix. pp. 680 and 681; *The Electrical Review*, vol. xl. p. 736 and 794; *The Contract Journal*, vol. xxxvi. pp. 1028 and 1029; *The Journal of Gas Lighting*, vol. lxix. p. 1240.

The power utilized might, however, vary between 25 per cent. and 95 per cent. The advantages of hydraulic lifting and pressing were that no brake was required, and full pressure and power was immediately at command, in spite of the intermittent nature of the work. Lifts were usually worked at speeds of 100 feet to 600 feet per minute. The ram-lift, although the simplest, safest, and cheapest to maintain, had usually a low efficiency. Hydraulic power was a valuable adjunct to the ordinary water-mains for fire extinction, 500 HP. being immediately available at any point on the London hydraulic system. The only equitable method of charging for hydraulic power was on a sliding scale, the price varying inversely as the quantity used. The average rate in London was under 3*s.* per 1,000 gallons. Forty per cent. of the total consumption in London during 1896 was taken at 2*s.* and under per 1,000 gallons, at 750 lbs. per square inch pressure. If 3,000,000 gallons per quarter were used, the rate was 1*s.* 6*d.* per 1,000 gallons. It was estimated that for hydraulic power to supplant private steam-plants for driving general machinery, the charge would have to be about one-third of this, which, under present circumstances, seemed impossible.

No. 3.

"The Transmission of Power." [1]

By JOHN HOPKINSON, Junior, F.R.S., M. Inst. C.E.

The five chief methods of transmitting power were: by (1) gearing and shafting; (2) ropes; (3) compressed air or steam; (4) electricity; (5) water. In all, except (3), the chief loss was due to some form of friction, electrical or mechanical. In the case of compressed air or steam, however, the losses were thermodynamic. Air became heated when compressed, and cooled when expanded. The heat of compression was dissipated before expansion took place, and the latter therefore led to low temperatures. These peculiarities render this form of energy especially useful in tunnelling, where the air was at once used for the

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[1] *The Engineer*, vol. lxxxiii. p. 535; *Engineering*, vol. lxiii. pp. 710 and 729; *The Electrician*, vol. xxxix. p. 149; *The Electrical Engineer*, vol. xix. pp. 680 and 681; *The Electrical Review*, vol. xl. p. 793 and 794; *The Contract Journal*, vol. xxxvi. pp. 1028 and 1029; *The Journal of Gas Lighting*, vol. lxix. p. 1240.

transmission of power, ventilating and cooling. Electricity had taken the field for tramways, except where gradients were too severe for ordinary adhesion working. It was doubtless destined to largely supplant other means of transmission, though each possesses its proper field.

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26 May, 1897.—*No. 1.*

"Important Questions in the Economic Working of Steam-Engines and Boilers."[1]

By Bryan Donkin, M. Inst. C.E.

Steam pressures between 150 lbs. and 250 lbs. per square inch were now used. Cylinders should be efficiently jacketed to obtain the best results, both on the barrels and covers. Clearance volumes should be as small as possible, and the surfaces flat and smooth. High revolutions and piston-speeds were now much in vogue, especially with single-acting engines. The superheating of steam, and the balancing and lubrication of moving parts, received more attention now than formerly. Steam-pipes and flanges should be well drained and clothed.

The efficiency of steam-engines was best expressed as thermal units per I.HP. per hour. Boiler efficiency was now more studied than formerly. Analysis of the chimney-gases was most important in boiler trials. Automatic stoking led to economy, but was less used in marine-work than might be expected. Water-tube boilers had largely come into favour during the last ten years, as had also feed-water heaters. The highest boiler efficiency was obtained with an evaporation of between 4 lbs. and 5 lbs. of water per square foot of heating-surface per hour. Generally speaking, internally-fired boilers were more efficient than those fired externally.

It was very desirable that all steam-engine and boiler results should be tabulated in a uniform manner. There was now much confusion, as experiments were published in various ways and under different headings by different authorities. The Author suggested that a small committee be appointed by the Council of the Institution of Civil Engineers with a view of determining the

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[1] *The Engineer*, vol. lxxxiii. p. 537; *Engineering*, vol. lxiii. pp. 735 and 758; *The Electrician*, vol. xxxix. p. 151.

best set of headings for the detailed statements of results. Such a standard method would be found very useful for a more rapid and accurate comparison of experiments. The proposed form should be as practical and simple as possible.

In the United States boiler experiments were now nearly always published in accordance with the uniform system of headings recommended and adopted by the American Institution of Mechanical Engineers. Any additions could be made by any experimenter at the end of the standard form to suit special requirements.

No. 2.

"Separate Condensing Plants."[1]

By HENRY DAVEY, M. Inst. C.E.

Appliances for economising condensing water were divided into (1) cooling ponds; (2) evaporative condensers; (3) atmospheric condensers; and (4) methods of cooling water to be used over and over again. (1) Cooling ponds required too much space for general adoption in towns. The Author provided 2·5 square feet of water surface, and 12·5 cubic feet of water per lb. of steam condensed per hour. (2) Evaporative condensers were now being rapidly developed. In general principle the steam was exhausted into a nest of tubes, down the outside of which condensing water trickled. The condensing effect was much augmented by an artificial current of air. After leaving the evaporative condenser, the steam might pass through a supplementary surface condenser. Power was required for circulating the water through the evaporative and supplementary condensers, and for working the air-pump and fan. From 1 lb. to 1½ lb. of condensing water was required per lb. of steam. The cooling surfaces should be not less than 1 square foot per 10 lbs. of steam per hour, and that of the auxiliary condenser 1 square foot per 55 lbs. of steam per hour. The weight of water circulated should be twenty times that of the steam. (3) The principle of atmospheric condensers was the same as that of evaporative condensers, except that the heat was abstracted by a current of air instead of by water. A large

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[1] *The Engineer*, vol. lxxxiii. p. 538; *Engineering*, vol. lxiii. pp. 738 and 759; *The Electrician*, vol. xxxix. p. 152.

surface was required. (4) Various methods of cooling condensing water were in vogue, such as spraying it in an artificial current of air, or trickling it over surfaces in thin films.

No. 3.

"Petroleum as Steam-Engine Fuel."[1]

By JOHN AUDLEY FREDERICK ASPINALL, M. Inst. C.E.

The chief liquid fuels were petroleum, gas-tar, creosote oil, and "green oil" from gasworks. Petroleum had been used for firing locomotives in Russia for some time, but its high price debarred its extensive use in England. With Lancashire coal at 9*s.* per ton, liquid fuel should cost 1*d.* per gallon to do equivalent work. Its advantages were that it was easily turned on and off, and was smokeless and portable. With proper precautions fire-box plates were not injured. The theoretical evaporative values for different kinds of oil compared with coal were as follows:—

	Lbs. of Water per Lb. of Fuel.
Pennsylvanian heavy crude oil	21·48
Caucasian light crude oil	22·79
Petroleum refuse	20·53
Good English coal	14·61

On the Great Eastern Railway, where liquid fuel was much used, two special openings through the fire-box casing admit the oil and air-jets from a Holden injector. The consumption was:—

			Lbs. per Mile.
When using coal only			35·4
" " " and oil combined	Coal	11·8	
	Oil	10·5	
			22·3
" " oil only			16·5

At present green oil from gasworks was used, having a specific gravity of 1·1 and a flash point of 220° F.

[1] *The Engineer*, vol. lxxxiii. p. 538; *Engineering*, vol. lxiii. pp. 738 and 745; *The Electrician*, vol. xxxix. p. 153.

27 MAY, 1897.—*No. 1.*

"Piston-Valves in Locomotives." [1]

By SAMUEL WAITE JOHNSON, M. Inst. C.E.

The difficulties which had hitherto prevented the adoption of piston-valves for locomotives were: (1) the constantly varying travel of the valve; and (2) the fact that for long distances locomotives ran without steam, during which time the pistons created a pumping action, drawing in smoke-box gases charged with grit and ashes, to the destruction of the valve faces. A good piston-valve, besides overcoming these difficulties, should allow the free escape of drain-water. The Author employed on the Midland Railway a piston-valve having at each end one ring of soft gun-metal, and one ring of harder gun-metal split into three segments. The segments were forced outwards against the face by the steam pressure, but were pressed inwards by the escape of drain-water. In conjunction with this valve was an automatic vacuum-destroying and lubricating valve, which, when the steam was turned off and the above-mentioned pumping action would otherwise commence, opened and kept the steam-chest flushed with a mixture of steam and air. The power required to work the piston-valve was one-sixth of that required for the ordinary slide-valve, while the loss by wear was also about one-sixth.

No. 2.

"Roller-Bearings." [2]

By WILLIAM BAYLEY MARSHALL, M. Inst. C.E.

The advantages claimed for roller-bearings were: (1) reduction in starting effort; (2) decreased tractive effort; and (3) economy in lubrication. Experiments showed that on a gradient of 1 in 20 the starting effort with roller-bearings was 23 per cent. less than that with ordinary bearings; on a gradient of 1 in 80, 50 per cent. less; and on a gradient of 1 in 140, 60·4 per cent. less. Another

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[1] *The Engineer*, vol. lxxxiii. p. 577; *Engineering*, vol. lxiii. pp. 775 and 798; *Industries and Iron*, vol. xxii. p. 490.

[2] *Engineering*, vol. lxiii. p. 776; *The Electrician*, vol. xxxix. p. 156; *Industries and Iron*, vol. xxii. p. 490.

set of experiments to ascertain the running friction, showed that the frictional resistance with roller-bearings was less than one-third of that with ordinary bearings. With a perfect roller-bearing no lubrication was necessary, but oil must be used to prevent rusting. A saving of 50 per cent., however, was effected, as compared with ordinary bearings. The engineer of the Blackpool Corporation Tramways had certified that 30 per cent. of electrical energy had been there saved by the adoption of roller-bearings. Roller-bearings were being extensively adopted, one interesting application being to the big bell of St. Paul's Cathedral.

No. 3.

"Pneumatic Grain-Elevators." [1]

By Charles Reginald Parkes, M. Inst. C.E.

This note described the Duckham system for raising grain from barges or ships by vacuum, and delivering it to warehouse floors by air-pressure. The elevator "Garryowen" on this principle, then at the Limerick Docks, was a vessel 170 feet long and 16 feet 6 inches deep, and was provided with propelling engines of 240 HP. The grain could be drawn up from four hatches at once, by flexible pipes, into the receivers on the elevator, a distance of 50 feet vertical and 100 feet horizontal. It then passed by gravity through the air-lock, which consisted of a box with two divisions, having an automatic see-saw motion, into 8-inch cast-iron delivery pipes, through which it was forced up to the apex of the warehouse roof, whence it was distributed by branch pipes. The total distance of delivery from the receivers was 55 feet vertically and 340 feet horizontally. The air-exhausting and pressure engines were of the horizontal type. Each end of each cylinder alternately exhausted from the grain elevator and compressed into the delivery pipes. The work to be done under pressure was greater than that under suction, and the correct relation between the two was maintained by adjustable inlet air-openings in the receiver, which reduced the vacuum in the suction pipes while increasing the pressure in the delivery pipes. Air-pressures of 10 lbs. per square inch did not injure the grain, and in fact the aërating action had a beneficial effect upon it.

[1] *The Engineer*, vol. lxxxiii. p. 577; *Engineering*, vol. lxiii. pp. 776 and 797; *Industries and Iron*, vol. xxii. p. 490.

SECT. IV.—MINING AND METALLURGY.

25 MAY, 1897.—*No. 1.*

"Dealing with Water in Pits during Sinking and in Permanent Work." [1]

By JOHN BELL SIMPSON, M. Inst. C.E.

The principal methods of dealing with water in sinking were: (1) by lowering into the shaft a bucket set of pumps, actuated by engines on the surface; (2) by suspending steam-engines and pumps, and lowering them as required; (3) by the Kind and Chaudron system of boring the shafts and encasing them with metal tubbing put in from the surface; (4) by the systems of Poetsch and Göbert of freezing the ground. The Author reviewed the conditions under which sinkings had been carried out where exceptional quantities of water were encountered, as, for example, at Murton colliery, Durham, where 9,300 gallons per minute were drawn from a quicksand of 30 feet in thickness, three pits with six engines, aggregating 1,580 HP., working eighteen sets of pumps. At Cadeby, Yorkshire, 7,000 gallons per minute had been lifted by three steam-pumps suspended in the shaft, with steam-cylinders of 8 inches diameter, and rams of 8 inches diameter. At Marsden, Durham, 9,000 gallons per minute were dealt with to a depth of 60 fathoms, when, as the feeders were increasing, the Kind-Chaudron process was successfully introduced. In similar cases on the Continent, the method of freezing the quicksand had been employed.

Until recent years, machinery for permanent pumping was not economical in the way of fuel, a consumption of 8 lbs. to 20 lbs. of coal per I.HP. per hour being usual. Twenty-five years ago, however, the Author introduced Cornish engines in the north of England, the coal consumption being reduced to 3½ lbs. The largest plant of this kind was at the Wallsend colliery, where there were two 100-inch cylinder engines of 9-foot stroke, each of 500 HP. The Author had also adopted the compound vertical beam-engine with fly-wheel, the engine pumping 2,500 gallons

[1] *Engineering*, vol. lxiii. pp. 712 and 730; *The Engineer*, vol. lxxxiii. p. 536; *The Colliery Guardian*, vol. lxxiii. p. 995; *The Mining Journal*, vol. lxvii. p. 739.

per minute from a depth of 360 feet, with a consumption of coal of 2½ lbs. per I.HP. Underground pumping-engines were now being largely used in cases where there was no fear of their being flooded. The coal consumption was, however, not much under 6 lbs. per I.HP. One of the largest underground engines was that at Powell Duffryn colliery, South Wales. It was of the Worthington type, having two tandem engines, each with three cylinders. It pumped 600 gallons per minute from a depth of 1,500 feet.

No. 2.

"Water in Deep Shafts."[1]

By Henry Davey, M. Inst. C.E.

The Author described the methods of dealing with waterduring sinking operations. The plunger lift had been so much inproved that depths of 1,000 feet might be economically dealt vith, so that one plunger lift might be used where four or six were formerly employed. The methods of pumping during sinking comprised: (1) the ordinary sinking lift for 200 feet; (2) singing steam-pumps in the shaft; (3) the ordinary sinking lift employed in two stages; (4) a short-lift sinking pump with fixed steam-pumps placed in the side of the shaft from time to time to relieve it. The Author was, however, of opinion that the work could be more economically accomplished by using a permanent engine, with its pumps put in during sinking.

In permanent pumping, with the engine at the surface, the Author urged the advantages of a long stroke. In the case of a shaft 3,000 feet deep, he had adopted a stroke of 14 feet No high-speed engine had ever beaten in economy the low-speed pumping-engine. Underground engines, for various reasons,were now less used than they were. Hydraulic transmission of power had been employed with considerable success, and had much to recommend it. Transmission by electricity or by compressed air did not lend itself to dealing with water in deep shafts.

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[1] *Engineering*, vol. lxiii. pp. 712 and 729; *The Engineer*, vol. cxxxiii. p536; *The Colliery Guardian*, vol. lxxiii. p. 995; *The Mining Journal*, vol. lxvii. p710.

No. 3.

"On Deep Levels in Mining Practice in the United Kingdom." [1]

By Bennett H. Brough, Assoc. R.S.M.

In view of the rapid exhaustion of the thicker and more accessible seams in the British coal-fields, and in view of the depressed condition of the metalliferous mining industry of this country, great importance attached itself to the future development of deep-level mining. The deepest mine in Great Britain was the Pendleton colliery, near Manchester, where the deepest workings were 3,474 feet below the surface. This depth had been largely exceeded in other countries, the Red Jacket shaft of the Calumet and Hecla mine, Lake Superior, being 4,900 feet deep, a colliery at Mons, Belgium, 3,937 feet deep, and the Adalbert shaft, Przibram, Bohemia, 3,672 feet deep. The obstacles to deep-level mining were the decreasing capacity of shafts, the increase of pressure, temperature and cost. These obstacles were considered by the Author, who concluded that mining in coal seams up to 6 feet in thickness might be carried on up to a depth of 4,000 feet. In the case of thicker seams, the limit of depth would be less. There were no difficulties peculiar to Great Britain in deep-level mining. If pumping, winding, and ventilation could satisfactorily be dealt with in a Lake Superior copper-mine nearly a mile in depth, there was nothing to prevent the same measure of success being attained in Cornwall.

No. 4.

"Prospects of Deep Mining in Cornwall." [2]

By William Thomas, Assoc. M. Inst. C.E.

At the present time the deepest mine in Cornwall—Dolcoath—was 2,600 feet deep. The shafts of the principal Cornish mines were altogether inadequate for the work required of them, and the

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[1] *Engineering*, vol. lxiii. p. 712; *The Engineer*, vol. lxxxiii. p. 536; *The Colliery Guardian*, vol. lxxiii. p. 995; *The Mining Journal*, vol. lxvii. p. 685.

[2] *Engineering*, vol. lxiii. p. 713; *The Engineer*, vol. lxxxiii. p. 537; *The Mining Journal*, vol. lxvii. p. 707.

tram roads were unsatisfactory. Tonnage costs were therefore increased in two ways. The practice had generally been to adhere to existing methods and appliances unduly. Recently, however, comprehensive schemes for placing the equipment of the leading Cornish mines on a more satisfactory footing had been carried out. New engines of modern type had replaced older ones, and deep, circular, vertical shafts were being sunk at Dolcoath and at the Basset mines. The system of centralization of work, rendered possible by these shafts, would greatly increase the output capacity and would effect a large saving in labour and in general working costs. Even then the aggregate working costs, which averaged 15*s.* to £1 per ton, were not high when compared with those obtaining in other districts.

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26 May, 1897.—*No. 1.*

"The Mechanical Appliances used by Metallurgists."[1]

By William Chandler Roberts-Austen, C.B., F.R.S.

The Author illustrated by a number of examples the handling of materials which were either charged into or issued from furnaces. He described the hydraulic pig-breaker used at the Dowlais Works, the Uehling pig-iron casting-machine used at the Lucy plant of the Carnegie Steel Company, and the Wellman electric machine for charging open-hearth furnaces used at the Otis Steel Works in the United States.

No. 2.

"Steel and Iron Alloys."[2]

By Robert Abbott Hadfield, M. Inst. C.E.

In the use of iron, the latest phase of development was found in its alloys with other elements. The Author cited the results of Professor Arnold's investigations of steel alloys, and briefly discussed the properties of his own experiments upon carbon steel,

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[1] *The Mining Journal*, vol. lxvii. p. 694.
[2] *The Iron and Coal Trades Review*, vol. liv. p. 791.

nickel steel, manganese steel, chromium steel, copper steel, and the alloys of iron with silicon and aluminium. A novel alloy, cobalt steel, prepared by the Author, had a number of interesting properties somewhat resembling those of nickel steel. Incidentally he pointed out that it was to be regretted that there was a great laxity of expression in defining the quality of hardness, and urged the importance of metallurgists and engineers coming to a clear and definite understanding as to the meaning of the term.

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27 May, 1897.—*No. 1.*

"The Kent Coal-field."[1]

By Robert Etheridge, F.R.S.

The Author gave an account of the discovery of coal near Dover, showing that an extensive and valuable coal-field existed in the south-east of England under conditions agreeing with those obtaining in the coal-fields of Belgium and the North of France. The Dover coal-seams appeared to be the same as those of the Belgian and French coal-fields, and were overlain unconformably by cretaceous and jurassic rocks. They were horizontal and regular, and the evidence afforded by fossil plants indicated the existence of a continental land surface ranging east and west to the western coal-fields of Bristol and South Wales. From scientific and commercial points of view, it would be of great interest to determine the position of the great underground range of coal measures connecting the Ardennes and the Mendips, a distance of 400 miles.

No. 2.

"West Australian Gold-Mining."[2]

By Charles Algernon Moreing, M. Inst. C.E.

The Author pointed out that the gold-fields of Western Australia covered 300,000 square miles, and commented on the barren nature of the country and the rapidity of its development. The gold

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[1] *Industries and Iron*, vol. xxii. p. 490; *The Colliery Guardian*, vol. lxxiii. p. 996; *The Mining Journal*, vol. lxvii. p. 692.

[2] *Industries and Iron*, vol. xxii. p. 490; *The Mining Journal*, vol. lxvii. p. 685.

deposits were of two kinds, quartz veins and composite veins. Extraordinary results had been obtained from these latter veins, notably by the Great Boulder Proprietary Company, who had crushed 21,020 tons of ore, and obtained from it 82,612 ozs. of gold, or 3 ozs. 18·6 dwt. per ton, and the Hannan Brownhill Gold Mining Company, who crushed 2,948 tons for a yield of 18,424 ozs., or 6 ozs. 5·0 dwt. per ton. It was interesting to note that ores of tellurium had been found in association with the gold. In conclusion, the Author discussed the machinery and methods of ore treatment. He suggested that the ore should, as it came from the mine, be dried and then crushed dry, the product being divided into two classes by air-winnowing, an easily percolable product and slime. These should be treated by cyanide solution, and the tailings by an amalgamation process.

Section V.—SHIPBUILDING.

25 May, 1897.—*No. 1.*

"Practical Application of Model Experiments to Merchant-Ship Design."[1]

By Archibald Denny.

The experimental tank at the Leven Shipyard was 300 feet long. For 250 feet it was 22 feet broad and 10 feet deep, and it contained in all 1,500 tons of fresh water. The remaining 50 feet consisted of two shallow docks, one at each end. By means of a false bottom the depth of water could be varied and its effect upon the resistance of a vessel ascertained. Suitably supported over the water was a double line of rails, on which ran a dynamometer truck and a screw truck drawn by an endless wire rope driven by an engine. The apparatus closely resembled that designed by the late Mr. W. Froude, and the experimental method was practically identical with that employed at the Admiralty experimental works at Haslar. Instances were given in which the tank had proved of great assistance to the firm, both in improving the form of vessels to fulfil certain conditions, and in determining suitable dimensions for the propellers. In one case the tank experiments showed that an increase of 3 feet in the beam of a 300-foot ship, the displacement and other dimensions remaining the same, would probably result in a gain of a knot in speed, and the prediction was verified by the result. As a result of a model screw experiment, a change in the propeller of certain ships gave an increase of ½ knot in speed. The tank was found especially valuable in ascertaining the wave contour on the sides of paddle-ships, thus making it possible to fix the best position for the wheels.

[1] *Engineering*, vol. lxiii. p. 713.

26 May, 1897.—*No. 1.*

"The Relative Advantages and Disadvantages of Rotary and Reciprocating Engines as applied to Ship Propulsion."[1]

By the Hon. Charles Algernon Parsons, M. Inst. C.E.

The advantages of the turbine system applied to marine propulsion were summarized as follows:—

Greatly increased speed, due to diminution of weight and steam consumption.

Increased carrying power of vessel.

Increased economy of coal consumption.

Increased facilities for navigating shallow waters.

Increased stability of vessel.

Reduced weight of machinery.

Reduced cost of attendance on machinery.

Reduced size and weight of screw-propellers and shafting.

Absence of vibration.

Lowered centre of gravity of machinery and reduced risk in time of war.

Up to the present no drawbacks had shown themselves or seemed likely to do so. The total weight of machinery in vessels of the torpedo-boat, or destroyer type, exclusive of boilers and auxiliary engines, on the turbine system would probably not exceed one-third that of ordinary engines of the same power, and speeds from 35 to 40 knots might be easily obtained.

In the "Turbinia," which had up to the present realized a mean speed of $32\frac{3}{4}$ knots on the measured mile, 100 HP. was developed per ton of machinery and nearly 50 HP. per ton of displacement.

[Note.—The Author states that since the reading of the Paper the "Turbinia" has had a larger steam-pipe fitted, and has been run at a steam-pressure corresponding to a speed of $34\frac{1}{2}$ knots, which was easily maintained.—Sec. Inst. C.E.]

No. 2.

"Use of Water-tube Boilers in the Mercantile Marine."[2]

By Albert Edward Seaton, M. Inst. C.E.

The Author was of opinion that, although there were many types of water-tube boiler in successful use, none altogether ful-

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[1] *The Engineer*, vol. lxxxiii. p. 540; *Engineering*, vol. lxiii. pp. 738 and 758.

[2] *The Engineer*, vol. lxxxiii. p. 541; *Engineering*, vol. lxiii. pp. 739 and 760.

filled the necessary conditions. He considered that a properly designed and properly worked water-tube boiler should not only be lighter, stronger, and more compact than a Scotch boiler, but that it should be equally economical in fuel, more durable and easier to repair at sea by the vessel's own staff. With the types in which the tubes were expanded in place, the first cost was little or no more than that of the ordinary boiler.

If the boiler were so designed that solid matter was deposited, not upon the generating tubes, but in places from which it could be readily removed, fresh water was no more a necessity than with the Scotch boiler. For passenger steamers pure and simple it was suggested that water-tube boilers were admirably adapted. For cargo steamers carrying passengers it had also many advantages, such as enabling a large amount of cargo or coal to be carried, due to the saving in weight of machinery. In cargo boats pure and simple the same arguments applied but with less force. There appeared to be good reasons for expecting the adoption of the water-tube boiler in the immediate future.

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27 May, 1897.—*No. 1.*

"Improved Materials of Construction, and their Influence on Design." [1]

By John Harvard Biles, M. Inst. C.E.

Improvements in design might be effected by changes in (1) arrangements of material; (2) strength of material; and (3) weight of material. Attention was called to nickel steel and aluminium. Nickel steel of 40 tons tensile strength had already been used in destroyers. It was considered that a tensile strength of 52 tons ultimate and 28 tons elastic might be accepted, as there seemed no great difficulty in making the butt-connections good. Resistance to compression was the vital question in the adoption of nickel steel. It would necessitate a reduction in frame-spacing accompanied by a reduction in weight of frame. Additional rigidity might be secured by the use of narrower strakes of plating and by flanging the edges between the frames. It was thought that 14 to 15 per cent. of the total weight of steel might be saved by the use of such material. On a 10,000-ton 20-knot

[1] *Engineering*, vol. lxiii. p. 776.

ship 1¼ knot additional speed could be obtained if the weight saved on hull were put into machinery, while a vessel of mild steel constructed to carry the same cargo at 21¼ knots would cost £70,000 more on account of the necessary increase in dimensions and power.

It was doubtful if any alloy of aluminium had been produced which would resist sea-water, but there were many parts of a vessel in which it might be profitably employed.

No. 2.

"Influence of Choice of Material and Workmanship on the Structural Strength and Durability of Merchant Shipping."[1]

By HENRY HARTLEY WEST, M. Inst. C.E.

An immense gain in strength and durability was secured by the changes from wood to iron as a shipbuilding material, since it then became practicable not only to attach securely the constituent parts of the outer skin to their supporting framework, but also adequately to fasten them to one another.

Modern steel ships, notwithstanding the great changes which had taken place in actual size and in the relations of length to beam and depth, were from the structural point of view fully as durable as iron ships, because, amongst other things, more attention was now paid to riveting; but they corroded more rapidly, especially in inaccessible parts, such as bunkers and double bottoms under boilers. The Author recommended the use of a bituminous composition for the protection of the bunkers and a liberal increase in the thickness of plating under boilers. He would welcome a transition to nickel steel if its use were properly safeguarded.

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[1] *Engineering*, vol. lxiii. p. 776.

SECTION VI.—WATERWORKS, SEWERAGE AND GASWORKS.

25 MAY, 1897.—*No. 1.*

"The Law and Allocation of Underground Water."[1]

By JAMES MANSERGH, Vice-President Inst. C.E. (Chairman of the Section).

In illustration of the difficulties which surround the subject of the right of ownership of underground water, the Chairman gave an account of a recent contest before a Commons Committee between the Corporations of Nottingham and Newark. It was stated that, upon the application of the Nottingham Corporation to the Local Government Board to extend their district of supply for their works by the addition of certain rural parishes, having an aggregate population of something over 3,000, they were met with a storm of opposition, and in the end the powers they sought were not granted. This was mainly because they were known to be making trial borings in the extended area, manifestly with the intention of sinking wells and erecting machinery in order to pump water away for the use of Nottingham. Among the opponents at this inquiry, the Newark Corporation were evidently the most seriously alarmed, because one of the proposed wells was within 2½ miles of the well supplying their own waterworks. Subsequently both Corporations deposited bills in Parliament; that in the case of Newark was to secure a protective zone of 4 miles radius round their well, while that of the Nottingham Corporation was to authorize them to make a group of three wells extending as far in one direction as 10 miles to the north of the site objected to before the inspector of the Local Government Board. A digest was given of the present state of the law on the subject of underground water-rights, and it was shown that, while in the case of surface streams, the law was clear, righteous and intelligible, the law relating to underground water required some amendment. The facts upon which the geological aspect of this particular case were based were set forth,

[1] *Engineering*, vol. lxiii. p. 835; *The Contract Journal*, vol. xxxvi. pp. 985 and 1026; *The Journal of Gas Lighting*, vol. lxix. p. 1240.

and the question of the amount of the percolation of the rainfall into the pebble-bed area was discussed. Another controversial question concerned the distance apart at which wells in the red sandstone might affect the water-levels in each other by pumping. The result of the protracted fight, which occupied nineteen days, was that the Nottingham Corporation were defeated in respect of two of their proposed wells, and the Newark Corporation acquired possession, not of the zone of protection, bounded by an 8-mile circle, which they sought, but of a somewhat more restricted area, together with larger powers than would seem to have been granted in any previous case.[1]

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26 May, 1897.—*No. 1.*

"Carburetted Water-Gas."[2]

By Corbet Woodall, M. Inst. C.E.

Allusion was made to the revolution brought about in the entire system of the supply of illuminating gas in the United States by the introduction of carburetted water-gas. It was not until 1890 that such gas was first made for distribution in this country by the Gas-Light and Coke Company at Beckton, and in 1897 the total quantity made in London and the provinces would probably reach 50,000,000 cubic feet daily, or 8 per cent. of the maximum output of the United Kingdom for lighting and other purposes. Water-gas was made by passing steam through a deep bed of incandescent coke or anthracite coal, and, while it was non-luminous when burned, its flame-temperature was even greater than that of ordinary coal-gas. Carburetted water-gas was prepared for lighting purposes by introducing into the water-gas in process of manufacture a hydro-carbon oil or distillate in quantity varying with the illuminating value desired. The plant employed for the manufacture was explained, and the process of first blowing air and then steam through a generator charged with coke to a working depth of from 5 feet to 6 feet was described by reference to a diagram. The gas generated was passed through two chambers, called respectively the carburetter and the superheater, and it was then purified

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[1] After this note was read the Newark case came before a Lords Committee, who decided not to confirm the protection given by the Commons.—Sec. Inst. C.E.

[2] *The Engineer*, vol. lxxxiii. p. 542; *Engineering*, vol. lxiii. pp. 742 and 761; *The Journal of Gas Lighting*, vol. lxix. p. 1241; *The Gas World*, vol. xxvi. p. 903.

in the usual manner. The cost of this gas was determined chiefly by the price at which oil could be bought. At the present values of $2\frac{3}{4}d.$ per gallon for oil and 15*s.* per ton for coke, gas of 20-candle power would cost 1*s.* 4*d.* per thousand cubic feet in the gas-holders. The chief use of carburetted water-gas in Great Britain had hitherto been in enriching ordinary coal-gas. Among the incidental advantages attaching to the manufacture of the gas in question were the small cost of plant for a given output, the lightness of the labour, and the reduction of the number of men employed, the fact that the plant was available at its full power within three hours of lighting up, and, lastly, the better price obtained for coke.

No. 2.

"Gas for Power Purposes."[1]

By JOSEPH EMERSON DOWSON, M. Inst. C.E.

The advantages of gas-engines, driven with ordinary town gas, as compared with steam-engines were set forth. It was generally admitted that with gas at 3*s.* per thousand cubic feet, the working cost of an engine, indicating more than about 30 HP., exceeded that of a steam-engine of a like power working under ordinary conditions. For large powers it was now usual to work a gas-generating plant in connection with the engine, which occupied the same ground space as a steam-boiler and needed the same type of fireman. The first engine driven with generator-gas was started in 1879. Engines of good make (indicating 50 HP. and upwards) consumed, when driven by generator-gas of average quality, about 1 lb. of fuel, whereas good steam-engines required 2 lbs. to 3 lbs. per I.HP. hour. It was necessary to employ anthracite coal or coke for the production of the generator-gas for engine work, though bituminous coal could be used to prepare the generator-gas for heating furnaces and other such work. Dr. Mond had, however, by working night and day, on a large scale, with special treatment of the gas, produced suitable generator-gas for engine purposes from bituminous coal. An important feature of gas was that it did not lose power on its way to the engine, on

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[1] *Engineering*, vol. lxiii. pp. 742 and 761; *The Engineer*, vol. lxxxiii. p. 542; *The Electrician*, vol. xxxix. p. 154; *The Journal of Gas Lighting*, vol. lxix. p. 1244; *The Gas World*, vol. xxvi. p. 904.

the contrary, the more the gas was cooled the better it was for the engine. Again, the stand-by loss of a steam-boiler was considerable, whereas that of a gas-generator capable of serving 200 HP. was only 3 lbs. to 5 lbs. per hour.

No. 3.

"House Sanitation."[1]

By Rogers Field, B.A., M. Inst. C.E.

The principles which governed the question of house-sanitation were briefly defined, and allusion was made to the Uppingham Regulations for House Drainage, drawn up by the Author twenty-one years ago, which were about the first of the kind embodied in by-laws allowed by the Local Government Board. With regard to the supply of water to dwellings the points which required attention were that the water should be pure, and that the appliances for its distribution should be so arranged that the water could not become contaminated before it was used. Where an independent supply had to be obtained, the sources of pollution were frequently numerous and insidious. For instance, a well might supply good water as long as only a small quantity was pumped, and bad water if the pumping were increased, as this might draw the water from a greater distance where sources of pollution existed. On the subject of drainage the two chief guiding principles were: (1) That all foul matter, directly it was produced, must be rapidly and completely removed from the house; and (2) That there must never be any passage of air from the drains or waste-pipes into the house. The first principle was far-reaching and went to the root of sanitation. The whole system of drains and sanitary apparatus must be carefully designed so as to be self-cleansing and readily accessible, and everything must be made thoroughly watertight. The second principle involved the isolation of the house-drains from the public sewer or outfall drain by a disconnecting chamber, the keeping the drains and pipes as far as possible outside the house, the disconnection of the waste-pipes from the drains, the ventilation of the drains, &c. Also, it was expedient to study the condition of the gas-pipes and fittings, which should always be tested by pumping air into

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[1] *Engineering*, vol. lxiii. p. 743.

them and watching thė result in a pressure-gauge. The Author stated in conclusion that one of the most important advances which had taken place in this branch of engineering in recent years was the general practice of applying searching tests to every detail of the work, special reference being made to the system of testing by air under pressure, brought forward by Mr. Charles Hawksley in 1884.

No. 4.

"Refuse Destructors."[1]

By Henry Percy Boulnois, M. Inst. C.E.

The quantity of refuse which had to be removed from houses and disposed of by the local authorities might be roughly estimated at about ½ ton per head per annum. By the use of a good refuse destructor the contents of the ash-pits or dust-bins, in lieu of being destroyed, were converted by heat into steam, vapour and various gases, leaving behind nothing but fine ash and clinker. As respected the site for the furnaces, ease of access was important, as cartage beyond certain limits would convert any saving by this process into a loss: steep gradients, either to the site or to the platform of the destructor, were obviously to be avoided. Strength of construction in all its details was essential, owing to hard usage, fluctuations of temperature and inconvenience caused by breakdowns. Ease of charging was very important, and any hand-picking or sorting of the filthy mass was to be deprecated. The question of the heat generated in a destructor furnace was the crux of all such processes; the temperature might range from 800° F. to 2,000° F. The avoidance of all nuisance in working the destructors was essential. Nuisances might arise from cartage of refuse to site, fumes or fine ash from chimney, from dust blown about, and from vapours of distillation arising from the charging platform. The best mode of counteracting these nuisances was discussed. Economy in working must be studied, as otherwise the process of burning the refuse would be abandoned for some less costly plan of disposal. The utilization of the heat generated had not hitherto been sufficiently attended to, and this might be carried out more effectually by placing the boilers in more direct

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[1] *Engineering*, vol. lxiii. p. 743.

contact with the heat than in the flues, and by increasing the heat in the cells. The Author laid down the conditions under which a series of trials might be made, in order to arrive at an approximation of the HP. derivable from a refuse destructor, though it must be remembered that house-refuse as a fuel varied in quality in every town—it varied with the seasons, it varied daily and almost hourly.

No. 5.

"The Bacteriology of Water-Supply."[1]

By Edward Frankland, M.D., D.C.L., LL.D., F.R.S., Hon. M. Inst. C.E.

It was pointed out that the bacterial examination of water used for dietetic purposes had of late years assumed great importance, chiefly because it had demonstrated that the domestic use of water which had been neither naturally nor artificially filtered was attended with serious risk in those cases in which such water had been previously exposed to excremental pollution. While it was necessary at the outset, to protest against the opinion that the presence of microbes in considerable numbers in potable waters caused such waters to be unwholesome, or at least suspicious, since there was no reason to suppose that even large numbers of non-pathogenic organisms were in the least harmful; it was no doubt of the utmost importance, during the prevalence of epidemic disease, to secure efficient bacterial filtration. As a standard of such efficiency, 100 microbes per cubic centimetre in the filtered water was not unduly severe. The chief topics to which the Author desired to direct discussion were: (1) Effect of floods on river microbes; (2) Effect of storage on the microbial contents of water; (3) Influence of initial bacterial impurity upon quality of filter effluent; (4) Influence of fineness and thickness of sand; (5) Influence of rate of filtration; (6) Effect of scraping filters. Under each of these heads the results of the most recent investigation were recorded, special attention being directed to experiments conducted in Germany, and in America by the Massachusetts State Board of Health, and to the Author's own experience gained

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[1] *Engineering*, vol. lxiii. p. 742; *The Journal of Gas Lighting*, vol. lxix. p. 1297.

during the past five years in the bacterial examination of the rivers Thames and Lea, and of the filtered supplies of the seven Metropolitan water companies drawing from these rivers.

No. 6.

"Relation between Rainfall, Flow off the Ground, Size and Actual Yield of Reservoirs."[1]

By WILLIAM FOX, M. Inst. C.E.

Reasons were given for commencing the yearly record of rainfall, upon which the size of storage reservoirs must be based, from the time that the drought ceased and the reservoir was likely to be emptied, say from the 1st October in each year, rather than from the date usually selected, namely, the 1st January. The deduction to be made from the rainfall to provide for evaporation and absorption in the hilly districts of this country was from 12 inches to 14 inches. The mode of estimating the daily average yield of any given area was explained. On the subject of the mean and annual rainfall, attention was directed to the Paper by Mr. A. R. Binnie, read before the Institution in 1892, and his figures were applied to a supposititious area of 4,000 acres with an average rainfall of 55 inches, 78 per cent. of the mean rainfall being taken as available. The duration and effects of drought for waterworks purposes, and the yield from a thunder-storm were discussed. The opinions of Sir Guilford Molesworth and Professor Symons were quoted respecting the deductions to be made for evaporation from the surface and for absorption. The annual loss from water stored from both causes in this country might be taken at something like 3 feet; this loss occurred mostly in the summer; and, if the reservoir were drawn down regularly, it would form a definite proportion of the whole depth and capacity; thus, if the reservoir were 50 feet deep, three-fiftieths of the total contents, and if 100 feet deep, three-hundredths of the total capacity would be lost.

[1] *Engineering*, vol. lxiii. p. 743; *The Journal of Gas Lighting*, vol. lxix. p. 1299.

Section VII.—APPLICATIONS OF ELECTRICITY.

26 May, 1897.—*No. 1.*

"Should Generating Plant be Mounted on Springs?"[1]

By James Swinburne, M. Inst. C.E.

The question whether moving machinery should be mounted on springs concerned both the welfare of the machinery, and the comfort of those who had to use it. Any imperfectly balanced machine must, while working, move its bed-plate if freely suspended, and the motion might be one of translation or of rotation according to the disposition and nature of the moving parts. The first instinct of the engineer in such cases was to increase the effective weight of the bed-plate by bolting down the machine to a mass of concrete, which in turn was sometimes isolated from the earth by mounting it on felt. The question was, why should not the bed-plate be mounted on springs and allowed free play? The Author had tried this arrangement on dynamotors in his own laboratory, and in Mr. Crookes' house, with conspicuous success. The idea was suggested by the Author anonymously in "Industries" in 1892, and Mr. W. W. Beaumont, by the introduction of his "vibromotor" principle, had put it in practice, especially in connection with flour-mills. The application of such a system to marine engines would be perhaps difficult, but would greatly increase the comfort of the passengers.

No. 2.

"The Application of the Steam Turbine to the Working of Dynamos and Alternators."[2]

By the Hon. Charles Algernon Parsons, M. Inst. C.E.

The first compound steam-turbine directly coupled to a dynamo was made in 1884. It ran at 18,000 revolutions per minute, and

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[1] *The Engineer*, vol. cxxxiii. p. 542; *Engineering*, vol. lxiii. pp. 743 and 762; *The Electrician*, vol. xxxix. p. 154; *The Electrical Engineer*, vol. xix. p. 682; *The Electrical Review*, vol. xl. p. 794.

[2] *The Engineer*, vol. lxxxiii. p. 543; *Engineering*, vol. lxiii. pp. 745 and 762; *The Electrician*, vol. xxxix. p. 156; *The Electrical Engineer*, vol. xix. p. 683; *The Electrical Review*, vol. xl. p. 796.

gave 6 electrical HP. Within the last five years direct-coupled turbine-dynamos and alternators of 500 to 700 electrical HP. had been constructed, and at the present time above 30,000 HP. of these motors were at work in England.

In the compound turbine of the "parallel flow type," the steam, entering by an inlet all around the shaft, passed through successive turbines of gradually increasing area of passage-way, and was expanded by small increments of volume at each turbine till it arrived at the next series of turbines. These were of larger diameter, and, consequently, greater peripheral speed and capacity, and allowed of farther expansion. Finally the steam flowed to the last series of turbines, where, the expansion being completed, it passed to the exhaust-pipe.

In the "radial flow type," the rows of turbine blades were keyed into and projected from the faces of moving disks attached to the shaft, and fixed disks attached to the casing. The course of the steam was outwards through the rings of blades, then inwards, and again outwards through the blades on the succeeding disk, and so on. The bearings were of special construction. Around the bush in which the shaft revolved were placed three concentric loosely-fitting tubes truly bored and centred, the action of which was to form extremely thin layers of oil around the shaft, which acted as a cushion and prevented hammering and vibration. The bearings were kept supplied with oil by a pump, and the end pressure of the steam was balanced by a rotating piston. A special form of governor, worked by a solenoid, was employed.

The first cost was smaller where turbines were used, and the maintenance was also less. This enabled more spare plant to be kept in readiness for heavy loads, especially as the machines occupied very little space. There was, moreover, no danger of injury through priming, and the exhaust steam was free from grease. The consumption of steam at average load was small, and there was very little vibration.

27 MAY, 1897.—*No. 1.*

"The Decimal System in Engineering Measurement."[1]

By M. HENRY P. RIALL SANKEY, Capt. R.E. (ret.), M. Inst. C.E.

After briefly discussing the advantages of the metric system, the Author described the results of its introduction into the works of Messrs. Willans and Robinson. Wherever gauges and templates were used, the question of their measurement in inches or millimetres was not a matter of much importance. The old drawings were therefore still employed for the earlier sizes of engine, but the templates and gauges were marked with the millimetre equivalent to the third place of decimals in order to accustom the men to the new unit. All new drawings were made on the metric system. Some difficulty was met with in connection with the screw threads. The Whitworth and gas threads had been retained, but the bodies of the bolts were turned slightly larger than usual for each size, so as to bring them up to even millimetres, and thus to enable the bored holes to take the corresponding screw cut to the standard used by the French makers of the engine.

After four years' working, the draughtsmen were practically unanimous in favour of metric measures, as being easier to check and to read, and requiring a smaller number of figures. No serious mistakes had been traceable to the change, and very few minor ones. In the shops, the old system was preferred at first, the new figures conveying very little idea of size, but the men were now much in favour of the millimetre. The works manager considered it easier to teach men the use of the rule with the metric than with English measures.

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[1] *The Engineer*, vol. cxxxiii. p. 574; *Engineering*, vol. cxiii. pp. 779 and 799; *The Electrician*, vol. xxxix. p. 157; *The Electrical Engineer*, vol. xix. p. 685; *The Electrical Review*, vol. xl. p. 870.

No. 2.

"The Equilibrium System of Feeding Electric Railways."[1]

By Charles Ernest Paolo Diana Spagnoletti, M. Inst. C.E.

The great desideratum in working an electric railway was that the potential on the line should be practically equal at all points of the conductor, and the Author proposed to attain this end in the following manner.

At each extremity of a line of railway, say 100 miles in length, he would establish a generating station connecting the positive poles of direct-current shunt-wound dynamos to each end of the conductor, the dynamos being equal in their output. If necessary, he would place additional dynamos, similarly connected, at intermediate points. With such a system no current would flow until a train was on the line, but at whatever point a train or trains might be taking current from the conductor, the potential would be practically the same, because the loss by resistance of the conductor from the distant stations would be made up by the stations to which it was nearer. An automatic electrical governor connected with the throttle-valve would shut off steam when no trains were on the line. Tram-lines at the various towns *en route* at which generators were established could be worked from the generating stations belonging to the railway companies and form tributaries to their line.

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[1] *The Engineer*, vol. lxxxiii. p. 574; *Engineering*, vol. lxiii. p. 780; *The Electrician*, vol. xxxix. p. 158; *The Electrical Engineer*, vol. xix. p. 686; *The Electrical Review*, vol. xl. p. 795.

SECT. II.—OTHER SELECTED PAPERS.

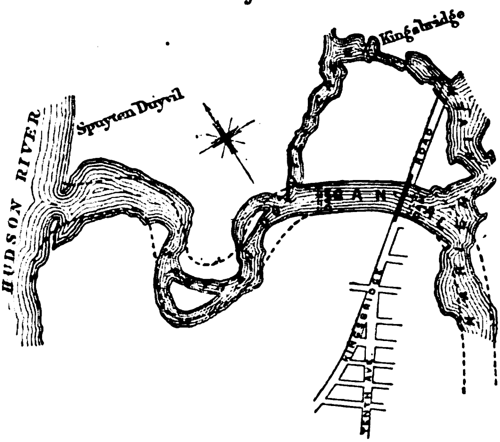
(*Paper No. 2942.*)

"The Harlem Ship-Canal Bridge."

By WILLIAM HUBERT BURR, M. Inst. C.E.

THE tidal stream connecting the Hudson River with the East River, near the junction of the latter with Long Island Sound, forms the northern boundary of Manhattan Island. To render this waterway accessible to vessels drawing 18 feet of water, the United States Government has constructed a canal 370 feet wide between bulkheads, and 18 feet deep at mean low water, along the line of Beekman's Creek, between two points of Spuytenduyvil Creek, *Fig. 1.*

Fig. 1.



Scale, 1 inch = 2,400 feet.

The structure which forms the subject of this Paper, Figs. 2, Plate 4, has been built across the Harlem Ship-Canal, on the line of Kingsbridge road, the old colonial highway, the extension of which southward is Broadway, New York. The United States law required the clear height of the bridge, above extreme high water, to be not less than 24 feet, to give unimpeded accommodation to small mastless craft; but the passage of masted vessels through the canal required the main superstructure to be a revolving swing-span. The requirements of such traffic are supplied by the two openings, one on each side of the centre pier, 104 feet 1 inch wide in the clear at mean high-water level. The two approach spans, which flank the swing-span, are each 100 feet long, from the centre of the pier

to the centre of the abutment bearing, and are of the ordinary riveted lattice type. The length of the structure is thus 551 feet 2 inches, from outside to outside of the abutment walls. The street traffic requires a width of roadway of 33 feet 6 inches between the curbs, and two foot-paths 8 feet 3 inches wide, making a total width of 50 feet.

Preliminary Operations.—A dam of sheet-piling and earth was constructed at each end of the ship-canal, at the two entrances to Spuytenduyvil Creek, to keep the water out of the prism during the excavation for the canal. These dams were carried about 4 feet above extreme high water, but subsequent events proved this to be insufficient. This portion of Manhattan Island consists in the main of a ridge of indifferent marble, unfit for any purpose except the coarser kinds of masonry, and nearly the entire length of the canal is cut through this rock. At the commencement of the work the excavation for the canal lacked but a low mound of about 600 cubic yards of rock of being complete. The dams had excluded the water, with the exception of a small quantity which leaked in at various points and which was readily removed by small steam-pumps. Inasmuch as the foundation sites of the three piers in the canal were placed on its floor or bottom, it was determined to found them completely in the dry, with the exception of pier No. 1, which would have required shallow sheet-piling only to enable the bed-rock to be laid bare. In April 1893, however, a north-east storm characteristic of the Atlantic coast set in, and the strong north-east wind which prevailed during three days caused an excessively high tide to overflow the two earthen dams, which were quickly washed away, causing the immediate filling of the canal prism.

To determine the character of the material through which the foundations would have to be sunk and to ascertain the depths at which the rock lay, twenty test-tubes were pierced in the vicinity of the two abutments and pier No. 1. Two-inch wrought-iron pipes were driven down with mauls, and the enclosed material was forced out through the annular space between them and inner $\frac{7}{8}$-inch pipes through which water was forced by a hand-pump. The general configuration of the greatest depths attained, compared with the information already gained in connection with the work on the canal, gave sufficiently reliable results. A fine freely running quicksand of variable depth, in which were found a considerable number of boulders, covered the rock; while above the sand was found the river silt and mud, and other sediment characteristic of the banks and

the beds of both Spuytenduyvil Creek and Harlem River. The general level of the water in this material was the same as that in the canal, and it rose and fell nearly coincidently with it. Although no foundation bed was more than 43½ feet below mean high-water level, it was determined to use pneumatic timber caissons for both abutments and pier No. 1, to avoid difficulties due to the presence of boulders in the quicksand which might attend the use of a cofferdam. The foundation beds for piers No. 2 and No. 3 were portions of the practically uniform rock bottom, and a cofferdam was used for the former and an open caisson for the latter. The bridge is near the eastern end of the canal, *Fig. 1*, close to the irregular line of intersection of the plane of the bottom of the prism with the sloping or shelving surface of the rock as it falls off rapidly toward the east. The position of the street was such that piers Nos. 2 and 3 could be placed on the bottom of the canal, but the irregular slope of rock prevented pier No. 1 from finding lodgment upon the same level, and necessitated its being founded upon a shallow pneumatic caisson, sunk to the sloping rock surface, Fig. 3.

Abutments.—The foundations for the north abutment were first placed. The material rendered the sinking of the caissons simple, but a considerable amount of rock-cutting in the working-chamber was necessary. As the face of the abutment wall was more than 60 feet in length, two caissons, 46 feet 6 inches by 26 feet 6 inches, were used for the foundations of the two retaining-walls, each of which was 40 feet long. An arch of 18 feet 3 inches span was then sprung between the two portions of the foundation, the crown of which was just below the surface, thus forming the support of a continuous abutment wall. The caissons were of timber, as their highest portions will always be 6 feet below mean low-water level. They were formed of 12-inch square yellow-pine, and were sheathed with 3-inch plank of the same material, Figs. 4, Plate 4. The working chamber was 8 feet high, and, even with the presence of such bracing as was necessary, afforded ample working space. It was lighted by electricity. The air-pressure at no time exceeded 18 lbs. per square inch. Two circular air-shafts, one for men and the other for material, were carried down through the roof of the caisson and were fitted with the ordinary air-lock for the men, and with the Moran lock for material. The latter is placed at the top of the shaft and carries two horizontal plates, each moved backwards and forwards by the piston in a small pneumatic cylinder, so that their two machine-finished faces are brought together with

an air-tight rubber gasket joint in the diametral plane of the shaft. A second air-valve or gate, similar to the upper one, is placed about 4 feet below the latter, giving a sufficient height to accommodate a cylindrical iron bucket, somewhat smaller in diameter than the interior of the shaft. The upper valve, at the top of the shaft, holds a small packing-box at its centre, when closed, through which a $\frac{3}{4}$-inch steel cable can run with small leakage of air. A derrick, the running line of which was a $\frac{3}{4}$-inch steel cable, swings its boom in place so that the material bucket is brought directly over the top of the shaft. The upper valve is then opened while the lower one remains closed, thus allowing the bucket to drop into the cylindrical space, which it closely fits, between the two valves. The upper valve is then closed, the packing-box being held tightly gripped when the two leaves of the valve come into contact, after which the lower valve is opened. The bucket is lowered into the working-chamber and filled with excavated material, and is immediately lifted into the space or chamber between the two air-valves or gates. The lower gate is then closed and the upper opened, thus allowing the bucket and its contents to be lifted into the air and deposited at any desired point. The cost of the work is thus materially reduced and its progress much facilitated. To secure a suitable foundation bed on the irregularly sloping rock surface, it was necessary to excavate the rock on that side of the working chamber which first touched it. The deepest excavation was 12 feet, in the east caisson, which brought about three-quarters of the entire area within the cutting-edge on the rock floor made by the excavation. The greatest depth of the rock surface below the cutting-edge on the down-hill side of the caisson was 5 feet, and the average depth about 2 feet. By slightly increasing the air-pressure and using sheet-piling driven with outward inclination under the cutting-edge, the material in this depression was excavated free of water, and a horizontal bench, 8 feet wide and of the full depth was excavated within it, as shown at X X, Figs. 4. The working-chamber, including the bench thus formed, was then filled with well rammed concrete, composed of 1 part (by volume) of Portland cement, 2 parts of clean sand, and 4 parts of fine grained strong limestone, broken to pass through a $\frac{3}{4}$-inch ring. The strata of rock were acutely inclined, and afforded, after excavation, sharply ragged points, producing the best holding surface for the concrete filling in the air-chamber.

On the top of each caisson a cofferdam was built of 6-inch by

12-inch yellow-pine scantling, sheathed with 12-inch by 3-inch plank of the same material, well caulked and braced, and Portland-cement concrete, in the same proportions as used in the working-chamber, but the limestone being broken to pass through a 2-inch ring, was placed within it. All the concrete was machine mixed, and it was deposited in 6-inch to 9-inch layers and well compacted with rammers weighing about 15 lbs. It was put in place with sufficient water to show a slight flushing at the surface in spots after thorough ramming.

The same general description applies to the four caissons for the south and north abutments. The borings showed the same abruptly sloping rock in all cases, with a few large boulders in the sand overlying the rock. The cutting-edges of the caissons were not carried down to a full bearing throughout their entire lengths, but in no instance, except that described for the east caisson of abutment No. 2, was it necessary to carry the benching down more than 3 feet below the cutting-edge to secure a full bearing under the working-chamber. The process was satisfactory with the latter depth, but with the greater depth of 5 feet it was conducted with less facility.

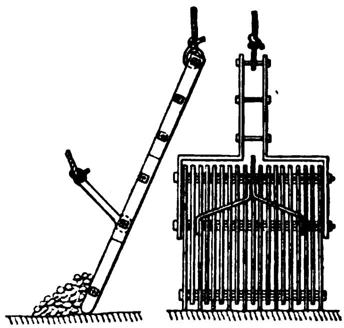
Pier No. I.—The description relating to the character and progress of the work in the caissons of the abutments applies also to the two smaller caissons employed for the two foundations for pier No. I. The two portions of the pier required small caissons only, about 26 feet by 16 feet, Figs. 3. As the two columns of masonry resting on these two caissons are subjected to the thrust of the arch, in addition to their vertical loads, their caissons were carried down into the rock until their cutting-edges reached a continuous support throughout their lengths.

Centre Pier.—The foundation for pier No. II, which is the pivot pier for the swing-span, was formed within a cofferdam, Figs. 5, Plate 4. The greater portion of the foundation lies on the roughly level rock-bed of the canal, but that a portion on the east side reaches over the natural slope of the surface. The entire foundation-bed was covered with mud and silt, which flowed in to a depth of 3 feet to 5 feet when the adjoining dam was washed away. This was cleaned off by dredging before the timber-work of the cofferdam was floated into place. The latter was framed with vertical and horizontal yellow-pine and hemlock timber, Figs. 5, in the water of the canal, at a short distance from the site of the pier. The timber framework was then drawn into position and sunk by piling stone on temporary platforms upon its top.

Its flexibility permitted it to adjust itself somewhat to the sloping surface of the rock on the east side of the foundation-bed, so that the opening between the two was at no point more than 18 inches. Canvas bags, holding about ¾ cubic foot of sand each, were thrown in close to and outside of the exterior shell of the dam, to prevent washing away of the puddle clay and gravel of the dam by the current, which, at certain stages of the tide, was very strong. A diver was sent down to arrange these bags to completely fill the openings between the exterior shell and the rock.

A sufficient number of holes, 4 inches in diameter, were made through the sides of the dam above low-water level, to permit the water to flow quietly in and out with the rise and fall of the tide, until, at a later condition of the work, it became desirable to exclude all water. At this stage the water inside the dam was without current under all conditions of the tide, so that the deposition of concrete under water could be made without wash. Before proceeding with this portion of the work, an annular surface on the foundation-bed, 8 feet wide and around its entire circumference, just inside the dam, was cleaned of dirt and loose material by a scraper, *Figs. 7*, to enable a close bond to be formed between the concrete and the rock-bed. The scraper was worked by ropes running over blocks held at suitable points around the dam and running to a hoisting engine, but it was guided by hand. The loose material was thus cleaned from the annular surface and scraped in toward the centre, where it was filled into buckets by divers and removed. The bond between the concrete to be deposited and the rock-bed was thus secured throughout a surface at least 8 feet wide and extending around the circumference of the base of the pier. The central portion of the bed was cleaned, but with a little less care than was devoted to the annular surface outside of it. There can thus be no danger of scouring under the concrete by the strong tidal currents, even though the lowest portion of the cofferdam should entirely disappear.

Figs. 7.

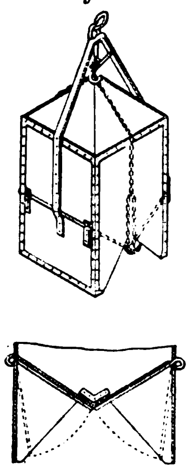


SCRAPER FOR CLEARING THE FOUNDATION.

The filling between the timber shells of the cofferdam was

composed of about equal parts of clay and gravel of all sizes, and no puddling, other than that resulting from dumping the material into the water, was used. The filling settled into a hard compact mass of a most satisfactory character. Its composition prevented any washing and subsequent falling in at any point. If any of the clay was washed away, the gravel settled into the opening and prevented further movement of the material. Before the filling was placed in the cofferdam, a sufficient quantity of concrete was deposited around and just inside it at the lowest points. The concrete flowed outward to a small extent and under the lower edge of the inner shell of the dam at all low points, and thus prevented any flow of the puddling material, as it was deposited, inward and under the concrete subsequently placed. After the completion of the cofferdam the mass of concrete forming the foundation of the pier up to 14 feet 9 inches (below mean high water) was deposited in skips or buckets holding 1 cubic yard each. This part of the work was carried on continuously day and night, to prevent the settling of laitance at any point. The time occupied was about 48 hours. Each bucket-load was successively deposited along a circular path to keep the centre somewhat low and so form a sufficiently inclined surface at all points to induce a movement towards the centre of any small amount of laitance that might be formed. The water was without current, and the bucket, *Figs. 8*, of large capacity for such a purpose (1 cubic yard), was so designed, and arranged with a tripping bottom, as to free itself of the concrete at the proper moment with the least disturbance of its contents. Each bucket, with its load, was first brought vertically over its point of deposition, and it was then lowered to the bottom of the water; the tripping-line was then drawn, and, as the bucket was raised, the concrete was left behind with a minimum amount of disturbance. The weight of the concrete thus deposited was a little less than the upward pressure of water beneath it, under the assumption that the water was present at all points with no leakage through the concrete. Blocks of stone were lowered on the concrete to prevent unbalanced upward pressure after the water was pumped out. As this part of the work was performed in mid-winter,

Figs. 8.



BUCKET FOR CONCRETE SETTING.

the concrete was allowed to set about 4 weeks before the coffer-dam was emptied by pumping. After that operation there was no leakage, and the surface of the concrete was quickly levelled to receive the first course of masonry. The concrete was found to be set very hard and in a satisfactory condition. The proportions of sand, cement and broken stone, viz., 1, 2 and 4 respectively, were such as to produce a very rich concrete, which is imperative for such work. The stone was broken to pass through a 2-inch ring, but the coarsest stone used was somewhat larger. After the completion of the pier, the upper part of the coffer-dam was removed to a level about 2 feet below low water, but the remainder was allowed to remain in place.

Pier No. III.—The foundation for pier No. III required different treatment, viz., an open caisson on an artificially levelled bottom, as shown in Figs. 6. A bottomless box was built of 6-inch by 12-inch timber, 27 feet by 17 feet 6 inches and 4 feet high, to which were secured 8-inch by 8-inch timber at the corners, and about 6 feet apart along the sides. These vertical pieces were capped by 10-inch square timber. The frame, with the bottomless box, was drawn into position and sunk to the rock. Concrete of the same composition as that used in the foundation of pier No. II was then deposited in the box, to a uniform depth of 2 feet, after the rock surface had been scraped and cleaned. A uniform surface of the concrete was secured by moving a rail over two others, which had previously been fixed at the proper elevation transversely to the longer axis of the bottomless box, and near each end. The latter rails were not removed, but remained in the concrete. The site of this pier was swept with strong currents at every ebb and flow of the tide, and hence the open framework was sheathed with 2-inch planks, for a height of 6 feet above the 6-inch by 12-inch timbers, which formed the case for the concrete. This sheathing, with the 6-inch by 12-inch timbers, formed a well 8 feet deep, in the bottom of which a 2-foot layer of concrete was deposited. The release, therefore, of the concrete from the skip took place in water with no progressive current, and with little, if any, eddying motions. This concrete was deposited in the same manner as that which formed the foundation of pier No. III. It was allowed to set about 3 weeks before receiving any load from the caisson and masonry above it. At the end of that time it was carefully examined at all points with iron sounding-rods, and found to be in a satisfactory condition.

The open caisson, in which the masonry of the pier was to be

built, was constructed in the water near the site. The platform bottom measured 24 feet by 14 feet 6 inches in outside plan, and was composed of two layers of 12-inch square timber, at right angles to each other, carrying a floor of 6-inch by 12-inch timber carefully caulked. The sides were formed of 6-inch by 12-inch and 3-inch by 12-inch planks framed and secured to 10-inch square and 4-inch by 10-inch scantling; they were also caulked with oakum, and were held in place by 1-inch rods with hooks at their lower ends, which engaged with staples in the platform floor. The caisson was floated into the framework attached to the bottomless box described, after the pieces at one end of the latter had been removed. The masonry of pier No. III was laid up in the open caisson, after the latter was in position, in the ordinary manner; and, after it was complete, the timber sides were removed by unscrewing the nuts at the upper ends of the 1-inch rods. After the completion of the pier, the remaining vertical pieces attached to the bottom of this box were broken off and removed, and concrete and rip-rap stone were deposited outside of and above the box encasing the concrete of the foundation, in order to preserve the timber platform and box from the attacks of teredo, although the purpose of the box was that of a mould for the concrete until it should become hard. The water of the canal is considerably freshened by the influx from the North or Hudson river, but there have been slight evidences of the teredo in the Harlem river. All permanent timber-work in the foundations of piers Nos. I and III is therefore protected. The foundations for the two portions of pier No. III were identical. The two greatest abnormal pressures on the foundation-beds are 5,220 lbs. per square foot under the centre pier, and 4,700 lbs. per square foot under the east portion of pier No. I. These pressures exist when the greatest possible moving loads are on the superstructure.

The masonry in the piers and abutments above the caissons and the concrete foundations is divided into two classes, viz., foundation masonry and finished masonry, the former having its upper limit one course below low water, and the latter reaching upward from the foundation masonry to the coping courses and newels. The foundation masonry consists of the best quarry-faced limestone ashlar laid to $\frac{3}{4}$-inch joints with Portland-cement mortar, composed of 1 part (by volume) cement to 2 parts of clean, sharp siliceous sand, with Portland-cement concrete backing, composed of 1 part of cement, 2 parts of sand, and 4 parts of stone broken to pass through a 2-inch ring. The finished masonry

is formed of quarry-faced limestone ashlar, of excellent quality, laid in Portland-cement mortar, 2 parts of sand to 1 of cement, with ½-inch joints backed with Portland-cement concrete of the same quality as that used for the hearting or backing of the foundation masonry, with the exception of the necking, belting, and coping courses, and the arch rings in piers Nos. I and III, which were of fine axed granite. The coping and necking courses, and the dressed work of the newels, are of light-coloured granite, but the remaining ornamental courses are of dark-red granite. The limestone is a dense fine-grained grayish-blue material from quarries near Canajoharie in the State of New York, while the granite was obtained from quarries in the State of Maine. The broken stone for the concrete was of a dense fine-grained material, free from pyrites, and well adapted to its purpose; it came from Hudson river limestone quarries. The ashlar facing of pier No. II was backed by a ring of closely-cut blocks of limestone, within which was placed the concrete hearting. This arrangement was adopted to present a cut-stone masonry support for the load of the swing-span, the entire weight of which rested upon this masonry shell. After the masonry was finished, all joints down to about two courses below low water were carefully scraped out to a depth of 2 inches or 3 inches, and pointed with Portland-cement mortar composed of equal volumes of cement and sand. The pointing mortar was finished with plane flush joints, worked hard and smooth with a pointing-tool.

Superstructure.—The supporting members of each approach span consist of three riveted girders about 100 feet long; one end of each of these centre girders rests upon the bridge seat immediately over the keystone of each arch in piers Nos. I and III. This arrangement imposes a load of about 85 tons on each keystone, and, as the arches are elliptical, the line of resistance passes outside of the arch ring at the springing joint. Since these piers are practically solid masonry, it is probably of little consequence where the line of resistance is found, but, as a precautionary measure against cracks in the arch ring, a riveted girder, 4 feet deep and 28 feet long, was built between the facing masonry of the spandrel walls over each of the arches in piers Nos. I and III. The practically identical coefficients of expansion of steel and masonry for changes of temperature gives to such a combination a very satisfactory character.

Swing-span.—The trusses of the swing-span possess a somewhat different outline than that hitherto adopted in American practice,

in that the centre lines of the top chords exhibit reversed curves. This outline was adopted to obtain a more pleasing appearance than that usually employed. The loads, working stresses, cross sections of the members and the results of computations with the various loads to produce the greatest stresses, are shown in *Fig. 9*. A possible snow-load of 20 lbs. per square foot of the entire roadway was assumed, as well as an uplift of 40,000 lbs. produced by the hydraulic locking machinery under each of the four end-posts of the swing-span. This uplift may be doubled without producing undue stresses in any member of the structure. Both the snow-load and the uplift were either recognized or ignored in the computations as was necessary to produce the greatest stresses in the members affected.

Fig. 9.

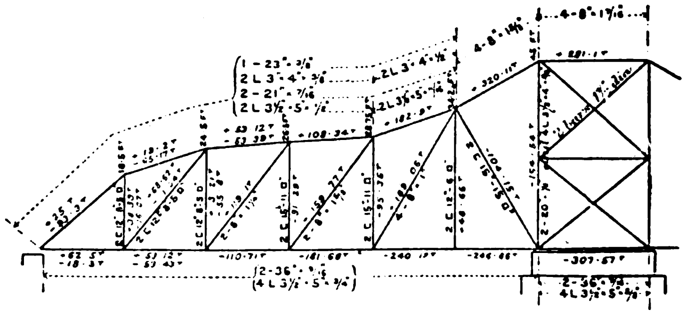


DIAGRAM OF THE SWING-SPAN.

Machinery.—The hydraulic locking and lifting machinery employed at the ends of the swing-span, Figs. 10, is actuated by high-pressure pumps of usual types, which force a mixture of glycerine and water into two vertical cylindrical steel accumulators, each 54 inches by 16 inches, placed in the engine-room in the drum of the turntable, whence 1½-inch pipes lead to the cylinders at the ends of the span. The piston-rods of these cylinders are connected, at one end, directly to the moving head of the toggle lifting- and locking-device. As the hydraulic piston moves toward or from the toggle, the end of the truss will rise or fall, as the locking- and lifting-block at the lower end of the toggle lever is seated in the pedestal on the masonry or rises from it. The other ends of the piston-rods connect through simple right-angled levers to the curved apron T-girders which rise and fall in the narrow circular opening between the ends

of the swing-span and the adjacent fixed spans. This apron girder is also curved vertically, to closely fit the crowning of the roadway, and is provided with a plate for its top flange which closes, when the bridge is closed, the narrow opening, and affords a continuous roadway surface for the traffic. The lifting machinery causes the apron girder to rise and fall 9 inches during the operations of opening and closing the bridge, while the locking- and lifting-block at the lower end of the toggle lever rises and falls, relatively to the end of the truss, but 6 inches. In actual operation the ends of the truss are forced up or lifted about 1 inch when the bridge is closed and locked. The seat of the lifting block, in the pedestal on the masonry, is provided with adjusting plates so that any desired amount of lifting of the ends of the trusses can be secured.

The working liquid contains 40 per cent. of glycerine, a larger percentage than is necessary to secure immunity from freezing at the lowest temperature of the coldest winter at New York. The machinery is designed to work, if necessary, at a pressure of 2,000 lbs. per square inch. The pressure is maintained in the accumulators by pumping the liquid against the proper volume of imprisoned air. A pneumatic accumulator is thus formed, and weights or similar appliances are obviated. The turning-engines and other operating machinery of the swing-span, together with boiler, gas-holder, water-tank and coal-bins, are placed compactly in the engine-room in the turntable. The turning-engine is of a usual double oscillating type, nominally of 45 HP., and communicates its power to the driving-shaft through a differential gear and friction-clutch. The boiler-pressure is usually about 70 lbs. per square inch. The general arrangements in the engine-room are shown in Fig. 11, and a section of the roller-path in Fig. 12.

Tests of Material.—The tests of eye-bars cut from bars of the same lot, given in the following Table, are of interest. The differences in ultimate resistances and ductility between the specimens and full-sized eye-bars are due partly to the differences in cross-section and length, but chiefly to the process of annealing to which the eye-bars were subjected in the process of manufacture. The Table shows the reductions in resistance and ductility which may be expected in passing from the specimen taken from the full-sized bar to the eye-bar manufactured from it. A somewhat high percentage of the eye-bars broke in the heads, but at such satisfactory ultimate resistances that no rejections were made on this account.

Size of		Elastic Limit per Square Inch of		Ultimate Resistance per Square Inch of		Final Contraction.		Final Stretch.		Fracture of Bar.
Bar.	Specimen.	Bar.	Specimen.	Bar.	Specimen.	Bar.	Specimen.	Bar.	Specimen.	
Inches.	Inches.	Tons.	Tons.	Tons.	Tons.	Per cent.	Per cent.	Per cent. Feet.	Per cent.	
8 by $1\frac{1}{4}$	$1\frac{1}{4}$ by $\frac{3}{4}$	17·64	12·01	25·60	29·19	4·36	49·8	5·03 in 30	24·5	In head
8 „ $1\frac{7}{16}$	$1\frac{7}{16}$ „ $\frac{3}{4}$	14·61	17·41	24·86	28·52	10·43	50·0	9·1 „ 19	26·5	„ „
8 „ $1\frac{7}{16}$	$1\frac{7}{16}$ „ $\frac{3}{4}$	13·51	17·18	23·26	28·54	55·7	53·35	15·9 „ 19	27·0	In body
8 „ $1\frac{5}{8}$	$1\frac{5}{8}$ „ $\frac{3}{4}$	14·62	17·19	24·32	28·35	50·4	49·2	15·35 „ 20	26·5	„ „
8 „ $1\frac{7}{16}$	$1\frac{7}{16}$ „ $\frac{3}{4}$	15·01	17·73	26·27	28·93	39·7	49·4	14·15 „ 19	27·5	„ „
8 „ 1	1 „ 1	15·64	17·23	25·66	28·50	56·00	44·7	12·61 „ 36	25·5	„ „

The final stretches of the specimens are for a length of 8 inches in every case. The completed eye-bar is seen to have its elastic limit (or, strictly speaking, its yield point) reduced 3,500 lbs. to 8,000 lbs. per square inch below that of the specimen cut from a bar of the same melting or cast, or possibly even from itself prior to the process of forging. The corresponding decrease in ultimate resistance varies between 6,000 lbs. and 11,000 lbs. per square inch. While these decremental results are larger than may usually be anticipated they satisfactorily exhibit the effects of the process of manufacturing steel eye-bars. The high elastic limit of 17·64 tons for the first specimen in the Table is exceptional. The percentages of final contraction for those bars which broke in the head are necessarily low because the contraction is measured in the body of the bar while the section of fracture is in the head. The diameters of the pin-hole in these bars varied between $6\frac{7}{16}$ inches to $7\frac{9}{16}$ inches.

Weights and Cost.—The summary of weights of metal in the structure is as follows:—

SWING-SPAN.

	Tons.
Turntable, machinery, &c.	169·09
Truss members	194·40
Test-bars	3·03
Floor	225·80
Lateral bracing	52·17
Railing	16·26
Bolts, rivets, &c.	9·25
	670·00

APPROACH SPANS.

	Tons.
Girders	126·52
Floor	141·57
Bracing	7·79
Railing	15·83
Bolts, rivets, &c.	6·18
	297·89

or a total weight of 967·89 tons.

The contract was let in April 1893, and the bridge was opened for traffic on the 1st January, 1895. The destruction of the earth dams delayed the beginning of the work about 3 months. The total cost of the bridge was £83,348 8*s*.

During the absence of the Author from New York some of the main features of the foundation plans were developed by Mr. A. P. Boller, M. Inst. C.E, who was then associated with him, and by Mr. George W. Birdsall, Chief Engineer of the Department of Public Works of New York City.

The Paper is accompanied by five tracings, from which Plate 4, and the *Figs.* in the text, have been prepared.

(*Paper No. 2995.*)

"Strengthening the East Row and Upgang Viaducts on the Whitby and Loftus Railway.

By William Robertson Lidderdale Forrest, Assoc. M. Inst. C.E.

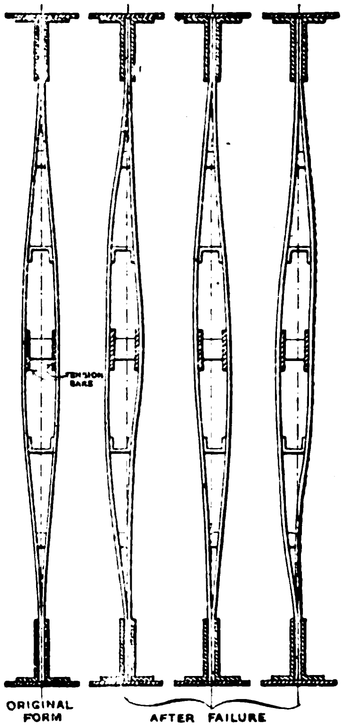
The Whitby and Loftus Railway connects the Whitby and Picton branch of the North Eastern Railway, and the Scarborough and Whitby Railway at Whitby, with the Cleveland branch of the North Eastern Railway at Loftus. In was constructed in the early seventies by the Whitby, Redcar and Middlesbrough Union Railway Company; the late Mr. John Dixon of London acted as engineer for the viaducts.

The railway crosses several ravines, varying in width between 300 feet and 1,000 feet, over which it is carried by the Staithes Viaduct, having six spans of 60-foot Warren girders, and eleven spans of 30-foot plate girders; the Upgang Viaduct, having five spans of 60-foot and one of 27-foot trellis girders; the Newholm Viaduct, having eleven spans of 30-foot plate girders; the Sandsend Viaduct, having eight spans of 30-foot plate girders; and the East Row Viaduct, having six spans of 60-foot trellis girders and two spans of 30-foot plate girders. These viaducts are all constructed for a single line of railway and are of the deck type. The main girders are spaced 7 feet apart from centre to centre, and are supported on piers composed of two tubular wrought-iron plate columns $\frac{5}{16}$ inch thick, varying in diameter between 2 feet 6 inches and 3 feet 6 inches, braced together and filled with concrete, and having cast-iron flanges standing on a foundation of concrete. The way-beams were originally carried on 5-inch by $2\frac{1}{2}$-inch by $\frac{7}{16}$-inch angle-iron cross girders.

The line was taken over by the North Eastern Railway Company in 1878, but before the Board of Trade would approve of it being opened for passenger traffic, longitudinal bracing had to be added between the taller piers, outside wrought-iron wheel-guards had to be provided, and the cross girders strengthened by having 6-inch by $2\frac{1}{2}$-inch channel-bars riveted to the angle-irons. This work was carried out by the Company, and the line was finally opened on the 3rd December, 1883.

The object of this Paper is to describe recent strengthening of the viaducts having trellis girders, viz., the Upgang Viaduct, which crosses a ravine a short distance north of Whitby at a height of 70 feet, and the East Row Viaduct, which crosses a portion of the seashore at about 35 feet above high water of spring tide, about 2½ miles north of Whitby. The main girders were 5 feet deep and had top and bottom booms composed of 9-inch by ⅜-inch plates, and two angle-irons 6 inches by 3 inches by 7/16 inch. They were divided into eleven bays of 5 feet, with a short piece of plate-web at each end. The diagonals of the four end bays were composed of two flat bars spread 4 inches apart at the intersection of the bracing. The bars in the end bays measured 6 inches by 7/16 inch, those in the second being 6 inches by ⅜ inch, and those in the third and fourth 5 inches by 5/16 inch. The bracing of the three centre bays was composed of 4-inch by 3-inch by 5/16-inch angle-irons. The struts were formed of flat bars, with distance-pieces placed about 15 inches apart. Many of these struts were found to have buckled considerably, *Figs. 1*, particularly those of the third bays, and two were completely broken through. The broken struts were temporarily secured with timber, 3½-inch by 3½-inch by ½-inch angle-irons were riveted on, and the work of strengthening the whole of the girders was then commenced.

Figs. 1.



Scale, ¼ inch = 1 foot.

BUCKLED STRUTS ON THE EAST ROW AND UPGANG VIADUCTS.

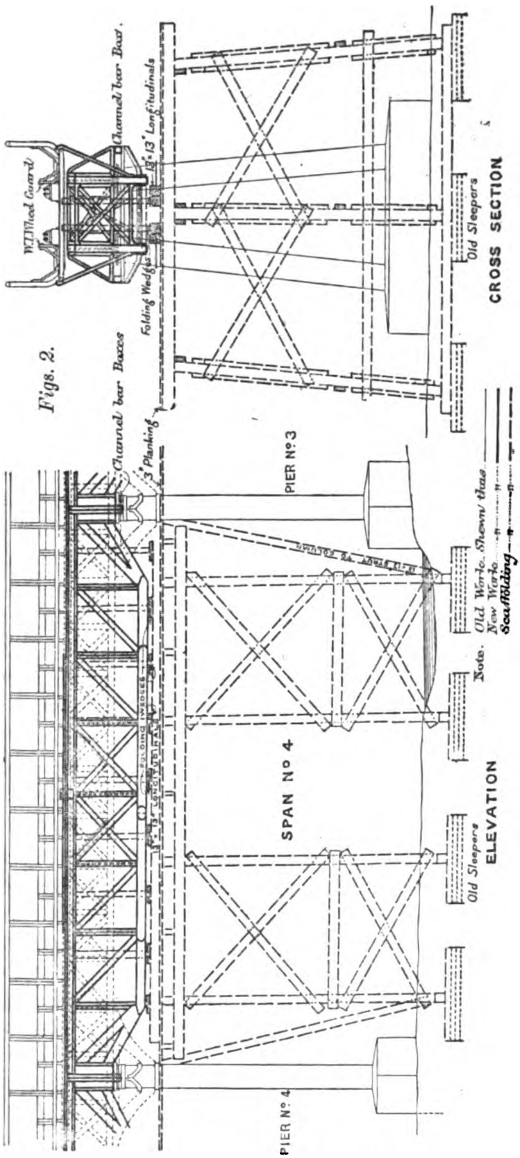
Upgang Viaduct.—The girders of Upgang Viaduct were strengthened by attaching to the old flanges a new system of N bracing, sufficiently strong to do the whole work. The verticals were each composed of two T-irons, those of the four-end verticals being 6 inches by 4 inches by ⅝ inch, and those of the three centre verticals being 6 inches by 3 inches by ½ inch. The diagonals

were composed of two flat bars varying between 8 inches by $\frac{5}{8}$ inch, and at the ends, 6 inches by $\frac{1}{2}$ inch, at the centre of the girder. In order to avoid interference with the traffic, or the cost of temporarily supporting the flooring from the ground, the old bracing was not interfered with, and the new bracing was attached clear of it. The new vertical posts were therefore placed midway between the old posts, and, with the diagonals, were bent out on either side to clear the old work. The new bracing was attached to the old flanges by $\frac{7}{8}$-inch gusset-plates inserted between the angle-irons of the flanges. The rivet-holes were drilled to template $\frac{1}{8}$ inch less than the finished dimensions, and were subsequently rimered out to the full size. The new bracing-bars and T-bars were sent to the site, having the holes at one end $\frac{1}{8}$ inch less than the full size. The work was then bolted together in position, and the holes requiring it were rimered to the full size. As soon as each hole was finished, a turned bolt was inserted, and when all the holes of one span had been completed, the work of riveting was commenced. No rimering or riveting was allowed when a train was on the bridge. Sufficient scaffolding was hung from the ends of the cross-girders to enable work at two spans to be carried on at the same time. In carrying out the work, 47½ tons of iron were used, the total cost being £714. The contract was entered into on the 6th December, 1893, and the work was finished by the 30th August, 1894.

East Row Viaduct.—At East Row Viaduct, owing to the extent of corrosion, and the generally bad condition of the trellis girders, it was decided to replace them by new steel girders of the N type of bracing, having vertical struts and inclined ties. The old trellis girders were 60 feet long and 5 feet deep, the ratio of depth to length being thus 1 : 12. The new girders are 7 feet 3¾ inches from centre to centre of the booms, thus increasing the ratio to 1 : 8. They are divided into eight bays of 7 feet 3¾ inches, the angle of inclination of the ties being 45°. The top boom is composed of two channel-bars placed back to back 9 inches apart, stiffened at intervals by 9-inch by 3-inch by $\frac{3}{8}$-inch channel-bars, additional sectional area where required being obtained by riveting plates to the top of the channel-bars. The bottom boom is composed of two flat bars placed 9 inches apart, and the area is increased where necessary by the addition of flat bars on the outside. Cross bracing is fixed between each pair of girders, which are 7 feet apart from centre to centre, at the first and third posts, and also over each pier. The cross girders are attached to

the new main girders by flat plates fastened to angle-cleats on the cross-girders by turned bolts; and they are also riveted to the top boom of the new girders. In designing the girders 20 per cent. additional sectional area was allowed to cover increase in the weights of locomotives and reduction of area by corrosion.

A substantial timber staging, *Figs.* 2, was constructed, from which the flooring of the viaduct was supported while the new girders were erected. It consisted of four trestles braced together in pairs, the



Scale, 1 inch = 20 feet.

RENEWAL OF THE GIRDERS OF THE EAST ROW VIADUCT.

whole being connected longitudinally at the top with 13-inch by $6\frac{1}{2}$-inch timbers spliced between the two pairs of trestles. The

sills of the trestles were supported on piers 9 feet by 9 feet, formed of sleepers laid across one another on the sand of the beach. A platform of 3-inch planking was carried on the crown trees and by intermediate cross-beams resting on the longitudinal timbers. The same staging was used for each span, each pair of trestles being rolled out intact from under the viaduct, and placed in position where they were next required.

While the staging was being prepared, men were employed in cutting out rivets, and replacing them with service bolts, and generally in preparing the work so that there should be as little as possible to do on the Sunday on which the new girders were to be placed in position. After possession of the line was obtained, generally shortly after 9 o'clock on the Saturday night, the girders were lowered upon the staging, each on its respective side, and were placed in cradles. Meanwhile all the bolts connecting the old girders with the flooring and adjacent girders were taken out, and the rakers to the flooring, and the brackets at the tops of the columns were removed. . After the girders had been lowered, the plate-layers disconnected the permanent way. The work of raising the flooring was then commenced by means of two 50-ton, two 40-ton, one 15-ton, and one 10-ton hydraulic jacks placed under the cross girders. As the flooring was raised, the folding wedges under the sleepers supporting the props to the cross girders were driven tight, this operation being repeated until the floor had been raised about 3 inches. When the flooring was raised the work of replacing the girders was commenced.

The crane-chains were fastened to the ends of the old girders on the north or sea side, and were tightened so as to ease the girder off its bearings. The girder was then swung out and placed on the bridge flooring. The old girder being out, the packing-pieces between the new girders and the cross girders were bolted on to the underside of the cross girders. The chains were then fastened on to the new girder, and it was swung into position, the operation being repeated with the south girders. The girders being fixed, the pier-brackets were placed in position, the flooring was lowered on to the girders, and the cross bracing was fixed in position. All the work was then bolted up, and the permanent way was re-connected.

The longest and shortest time occupied in the erection of a pair of girders is shown in the Table on the following page.

The number of men employed continuously on the erection averaged thirty; these were augmented on Sundays, when the new girders were erected, by a gang of six men. Two 10-ton

Stage of Work.	Longest Time. 21st July.	Shortest Time. 8th September.
Possession of line	9.15 P.M. 20th July	11.0 P.M. 7th Sept.
Girders lowered on to staging .	1.50 A.M. 21st July	12.15 A.M. 8th Sept.
Flooring raised	7.30 " "	4.0 " "
North girder out	8.15 " "	5.55 " "
New girder in	11.15 " "	7.0 " "
South girder out	12.5 P.M. "	7.12 " "
New girder in	3.0 " "	8.15 " "
Flooring lowered and bolted up .	4.30 " "	9.50 " "

steam-cranes were used. The quantities and cost of the work were as follows:—

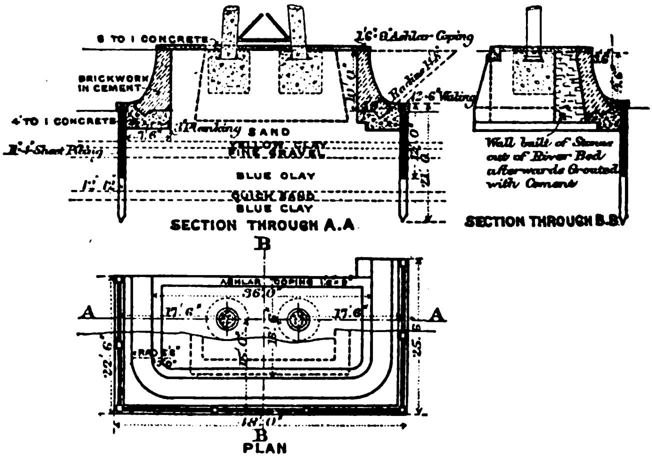
	£	s.	d.
Six pairs of girders with intermediate cross bracing weighing 101 tons at £10 per ton	1,010	0	0
Pier brackets, T-iron stays, &c., weighing 9 tons 13 cwt. 3 qrs. at £13 10*s*. 0*d*. per ton	130	15	8
Erection, including scaffolding, six spans at £220 per span	1,320	0	0
Sundries	107	10	7
Total cost of contract work . . .	2,568	6	3
To this amount must be added the cost of crane and engine power, new bedstones, and assistance from platelayers amounting to	114	8	6
Total	2,682	14	9

The contract was entered upon on May 9, 1895, and the work was finished by the 31st October, 1895, the contractors for this, as for the Upgang Viaduct also, being the Cleveland Bridge and Engineering Company of Darlington.

Shortly after the erection of the first pair of girders, a severe storm passed over the district, causing the stream under the fourth span of the viaduct to be flooded; and, owing to the obstruction of the scaffolding and the debris brought down by the flood, the waterway became blocked, and the stream diverted its course and cut out a channel under the fifth span 2 feet 6 inches deeper than the original channel, clearing away some of the sand for a depth of about 2 feet 6 inches below the foundations of the fifth pier. As a temporary measure a dry wall of large stones was built in front of the concrete, *Figs. 3*, and as soon as possible this wall was grouted with cement mortar. Sheet piling was driven in front of the rubble wall and returned at each end into the bank. The main piles were driven 21 feet and the sheet piles 12 feet through the sand into blue clay; 12-inch by 6-inch walings were bolted to the top of the piles, the top of the walings

being about 1 foot above the level of the sand in the river-bed. The sand behind the piles was excavated in short lengths to a depth of 18 inches below the toe of the rubble wall for a width of 4 feet in front and of 7 feet 6 inches at the ends; concrete was then deposited and a brick wall built in front of and against the rubble wall, the thickness averaging about 2 feet 6 inches. This brick wall was turned round the ends into the bank. The brickwork was built up to the level of the road under the sixth span, about 8 feet 6 inches above the top of the walings. A dwarf wall was built along the back joining the ends of the two

Figs. 3.



Scale, 1 inch = 32 feet.

REPAIR OF THE FOUNDATIONS OF PIER No. 5, EAST ROW VIADUCT.

end walls, and the enclosed space on the top was covered with a layer of concrete about 9 inches thick, the whole being finished off with an ashlar coping 18 inches by 9 inches. This work was carried out by the Company's staff.

The works were carried out under the supervision of the Railway Company's Engineer, Mr. W. J. Cudworth, M. Inst. C.E., under whom the Author was employed on the drawings and as Resident Engineer.

The Paper is accompanied by four tracings and nine photographs, from which the *Figs.* in the text have been prepared.

(*Paper No. 3035.*)

"Hydraulic Life-boats."

By SYDNEY WALKER BARNABY, M. Inst. C.E.

THE long-continued efforts of the Royal National Life-boat Institution to discover a suitable means of propelling life-boats mechanically have been described by Mr. Joseph Green.[1] They included the offer, in 1886, of gold and silver medals to competitors all over the world for models or drawings of mechanically propelled boats best adapted to meet the conditions under which life-boats work, and culminated in 1888 in an order being placed with Messrs. R. and H. Green of Blackwall for the construction of a vessel to be propelled by a centrifugal pump on the "hydraulic" system. The decision to adopt this system was arrived at on the recommendation of Mr. G. L. Watson, the Naval Architect of the Life-boat Institution, after consultation with Messrs. Green and with Messrs. J. I. Thornycroft & Company of Chiswick, to whom the construction of the machinery was to be entrusted, and who had previously built an experimental torpedo-boat for the British Government propelled in the same manner. The chief reasons for adopting hydraulic propulsion, as to the economy of which no illusions were cherished, were that, while a paddle or screw would be much exposed to injury from floating wreckage or from striking the bottom, an internal propeller would be in a position of great security; and further, a screw at the stern would be subject to racing in a life-boat, as the draught of water is small, but the inlet to the pump, being amidships, is always immersed, however much the boat may pitch. It was also thought desirable that the boat should be able to proceed under sail in case of accident to the machinery, and the internal propeller offers the least impediment to her doing so. Mr. Green described the "Duke of Northumberland," the first steam life-boat, and gave some account of rescue work done by her, in which she had proved to be very capable and efficient. The subject of hydraulic propulsion has been dealt with by the Author in a previous Paper,[2] and the object of this Paper is to describe the

[1] Journal of the Society of Arts, vol. xxxix. p. 127.
[2] Minutes of Proceedings Inst. C.E., vol. lxxvii. p. 1.

latest steam life-boat, Figs. 1 to 6, Plate 5, which has been built by Messrs. Thornycroft & Company for the South Holland Life-boat Institution, and which is stationed at the Hook of Holland.

The vessel was designed by Mr. G. L. Watson, who furnished drawings and a specification, the builders being responsible for the design of the machinery and for the attainment of a speed of 8½ knots. The particulars of the vessel, which is named the "President van Heel," are:—

Length over all	55 feet.
Length on W.L.	53 feet.
Breadth, moulded	13 feet 6 inches.
„ over sponsons	15 feet.
„ extreme over belting	16 feet.
Depth, moulded	5 feet 6 inches.
Draught, extreme	3 feet 3 inches.
Displacement	30·8 tons.
Block coefficient of fineness	0·465
Prismatic „ „	0·572

The hull is of galvanized mild steel, having a tensile strength of 26 tons to 30 tons per square inch, and an elongation of 20 per cent. in a length of 8 inches. The plating weighs between 7½ lbs. and 4½ lbs. per square foot. The seams are double riveted, and the butt laps are treble riveted in way of engine and boiler-rooms and double riveted elsewhere. The hull is closely subdivided, and the bulkheads are intact, the only watertight doors being in the coal-bunker bulkheads. Access is obtained to the small compartments for the purpose of examination and painting by manholes jointed with red lead in the bulkheads above the water-line. Longitudinal wing bulkheads extend for a length of 25½ feet on each side, enclosing the machinery space. They are 2 feet 6 inches from the side at the height of the water-line amidships. They considerably reduce the volume of the machinery compartments, which are unavoidably long, and afford security in case of injury to the boat's sides. The wing compartments are subdivided by athwartship bulkheads, and on each side of the boiler-room one of the compartments thus formed is used as a coal-bunker. Two strong side protective keels of American rock elm are fitted between angle-bars, the bolts going through the flanges of the bars, and not through the bottom plating. These are placed under the longitudinal side bulkheads, and are an effective protection to the pump inlet and to the bottom. On one occasion when proceeding to a wreck, the life-boat struck on the sands at the mouth of the Maas and was left there by the tide. She was bumped severely on the sands as the waves alternately lifted and dropped her, but

no leak was started, nor was the hull in any way injured. In the stern is an open cockpit capable of holding about forty-five people. The deck of the cockpit is above the water and water-tight. It is provided with the usual freeing valves to allow of the rapid exit of water in case of a sea being shipped. The rudderhead is hexagonal in section for a length of about 2 feet, and can slide up and down in a quadrant into which is geared a worm-spindle which carries the steering-wheel at its inboard end. The rudder can rise if it strikes the bottom, or can be triced up with tackle provided for the purpose without disconnecting the steering-gear. A liquid compass and binnacle stand upon the deck of the cockpit, and the handles for directing the water-jets either ahead or astern are placed one on each side of the steering-wheel. The vessel is very easily managed by means of the jets. An experiment was made with the object of ascertaining in how short a time a lifebuoy dropped overboard could be recovered when proceeding at full speed, and whether the most expeditious method would be to turn at full speed towards the object, using the rudder only, or to reverse the jets and proceed to it astern, using the jets for steering. It was found that by either plan the lifebuoy could be recovered in one minute. At the forward end of the cockpit, upon the engine casing, is a steam capstan, made by Messrs. Thomas Reid and Son of Paisley, and a steel wire-rope hawser is coiled on a reel close to it. A wire-rope nipper is placed upon the forecastle, and an arrangement is provided for cutting the hawser in case of need. There are two sails, Fig. 2, a dipping lug and a forestay sail. The mast can be hinged down upon the top of the boiler casing.

The engine is inclined, and is of double compound surface-condensing type, having cylinders 8½ inches and 14½ inches in diameter, and a stroke of 12 inches. The cylinders are inclined to each other, and actuate a single crank on a nearly vertical shaft. The air-pump, bilge-pump, and two feed-pumps are driven by the main engine. A circulating-pump with an independent engine supplies water to the condenser. An auxiliary feed-pump is placed in the boiler-room. The main turbine and casing are of gun-metal, precautions being taken by means of zinc protectors to prevent galvanic action between the pump and the shell of the boat, should the zinc coating of the latter be worn off. The inlet-pipe is of steel, and the discharge-pipes are of copper. The diameter of the turbine is 2 feet 6 inches, and at a speed of 9 knots the discharge is about 1 ton of water per second. The thrust of the propelling jets was measured by mooring the stern to a

dynamometer, and was found to be 1·1 ton. The nozzles are 9 inches in diameter. In the hydraulic torpedo-boat referred to, it was of the first importance that the amount of water carried should be as little as possible, in order to keep the weight down, and the discharge-pipes were therefore taken direct from the pump to the side, and an external nozzle above the water-line could be turned either forward or aft. It was considered that an external reversing nozzle would be a source of danger to a life-boat, as it ran a risk of being injured, and possibly jammed, if struck; and weight being of less importance, it was preferred to carry the discharge some distance forward and aft, as shown in Figs. 3. The distributing- or reversing-valves are placed at the junction of the ahead and astern discharge-pipe. A greater weight of water has to be carried, as all the pipes are full, although only two may be in use; but the bends are easier, and the water has not to be lifted when the vessel is propelled ahead, the after nozzles being below the water-line. The nozzles for propelling astern are above water, and are protected by the belting. Figs. 4 and 6 are sections through the inlet and "ahead" and "astern" outlets, and Fig. 5, Plate 5, gives a section through the boiler-room. *Fig. 7* shows diagrammatically one of the reversing-valves. These are gun-metal castings bolted to the pump casing. They are square in cross-section, and the valve V, which is pivoted at P, moves from side to side and directs the water into the ahead or astern pipes as desired. When placed in mid position dividing the stream, the boat remains stationary. The inlet is formed in the same manner as in the hydraulic torpedo-boat, and described in the Author's Paper referred to, and its advantages have again proved to be great. The features of the design are that the water is conveyed to the pump without shock, and the cross-sectional immersed areas of the hull in way of the inlet are so formed as to allow the water to enter the pump without disturbing the natural flow of the stream-lines.

Fig. 7.

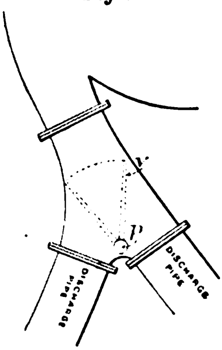


DIAGRAM OF A REVERSING-VALVE.

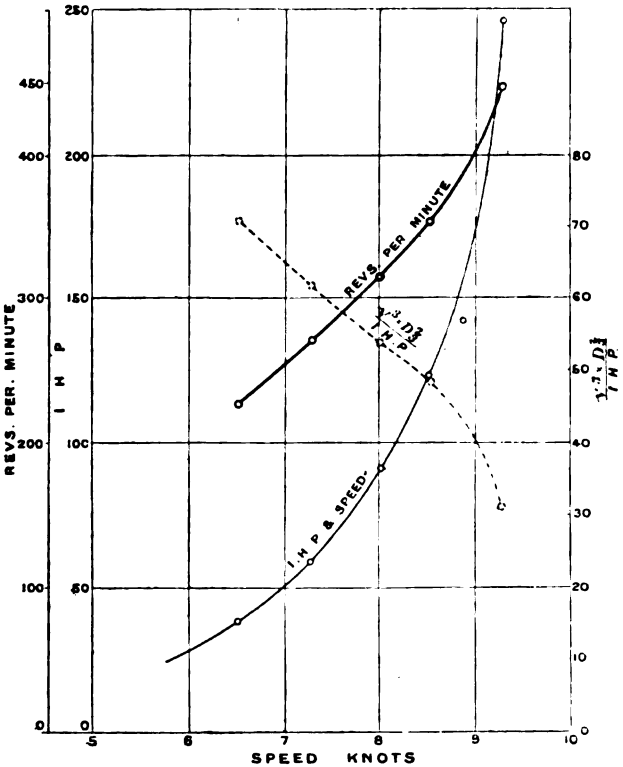
The boiler is of the Thornycroft water-tube type. It does not prime, although the movements of such a small vessel in a sea-way must be violent. Steam can be raised from cold water in 20 minutes. The tubes are of galvanized steel. The effective heating surface is 610 square feet, and the grate-surface is 11·4 square feet.

The weights of the vessel are:—

	Tons.
Hull	11·23
Fittings	1·77
Woodwork	1·61
Propelling machinery	7·89
Engineers' stores	0·33
Boatswain's stores	0·30
Fuel, crew and passengers	6·95
Total	30·08

The metacentric height with all weights and a full load of

Fig. 9.



RESULTS OF PROGRESSIVE SPEED TRIALS OF THE HYDRAULIC LIFE-BOAT "PRESIDENT VAN HEEL."

passengers on board, is 1·77 foot. Fig. 8, Plate 5, is the curve of stability under these conditions.

By permission of the South Holland Life-boat Institution a series of trials was run on the 19th February, 1896, over the measured mile at the Hook of Holland, to measure the I.HP. required to drive the vessel at different speeds. The results are shown in *Fig. 9.* The boat was brought to a draught of water corresponding with a displacement of 30·08 tons. It will be seen from the I.HP. curve that up to a speed of 6½ knots the performance is fairly economical, but after this speed the power-curve rises rapidly. The guaranteed speed of 8½ knots was obtained with 123 I.HP., the engines working at half-power. With 246 I.HP. the speed was 9·29 knots. Much power is wasted by a hydraulic propeller when driven far above its designed speed. This, together with the fact that the length and form of the boat were not adapted for speeds above 8½ knots, accounts for the extremely rapid rise of the power-curve, which appears to be almost asymptotical to a speed of 10 knots, that is to say, it would not seem possible to obtain that speed however fast the turbine might be driven. The object of providing such a large reserve of power in the boat was not that she might be driven at a higher speed than 8½ knots, but to insure that the power wanted for this speed might be obtained without difficulty under the arduous conditions of the service.[1]

The Author is indebted to the officials of the South Holland Life-boat Institution for courteously putting the boat and crew at his disposal for the purpose of these trials, and to Mr. Thornycroft Donaldson, M.A., and to Mr. G. W. Leeson, Studs. Inst. C.E., for assistance in making them.

The Paper is accompanied by five tracings, from which Plate 5 and the *Figs.* in the text have been prepared.

[1] A new vessel is being built by Messrs. J. I. Thornycroft & Company for the National Life-boat Institution closely resembling that described in the Paper, the only important difference being that provision is made for the use of oil-fuel as well as of coal.

(*Paper No. 3036.*)

"Alternating-Current Dynamo Tests."

By Horace Field Parshall, M. Inst. C.E.

The object of the following investigation was to measure the efficiency of a large alternating-current dynamo at different loads; to obtain definite quantitative results regarding armature reaction and its effect upon the field-magnets, and upon the form of the electromotive-force curve; to subdivide and locate the elements of the total losses in the machine; and to establish an economical, accurate and comprehensive method of testing. The efficiency of large machines has hitherto been only indirectly measured, by determining the efficiency of the engine or other prime mover, and comparing this with the combined efficiency of the prime mover and the dynamo. It is generally understood that the efficiency of an alternating-current dynamo under load cannot be predicted from no-load trials, as in the case of continuous-current machines; for, whereas in a continuous-current dynamo the reaction of the armature on the field-magnets may be expressed in the same terms as the effect of the field-magnets on the armature, as is shown by Drs. John and Edward Hopkinson,[1] in an alternating-current machine, when the current is in phase with the electromotive force induced by the magnetism of the field-magnets, there is no corresponding armature reaction, as in a continuous-current machine when the brushes are set symmetrically with respect to the polar projections. When, however, the current is displaced in phase from the electromotive force, it reacts on the field-magnets, and, in the case of lagging current, tends to diminish the magnetization of the field; or, in the case of a leading current, such as would occur in a dynamo acting on a system of sensible capacity, it tends to act with the field-magnets, such effect being proportional to the angular displacement of the current with respect to electromotive force. This, in a general way, corresponds to the angular lead of the collecting

[1] Philosophical Transactions of the Royal Society, vol. clxxvii. p. 331.

brushes in a commutating dynamo. Owing, however, to the effect of alternating currents and self-induction of the armature coils, currents are set up in the mass of the field-magnets, of double the frequency of the generated current. These local currents tend to demagnetize an alternating-current dynamo in the case of lagging current, or to increase the magnetism in the case of a leading current. Further, owing to the mutual induction between the armature and magnet coils, and the self-induction of the armature, the current in the field-magnet coils is to some extent reduced. The nature and theory of these phenomena have been set forth by Dr. John Hopkinson and Mr. E. Wilson.[1]

The method of test followed was that devised by Dr. John Hopkinson.[2] Two similar machines were rigidly connected by a coupling which admitted of the angular position of one armature varied relatively to the other, the power for driving being supplied by shafting through a specially-designed dynamometer. When two alternating-current dynamos are connected in parallel, whether or not current passes between them, the work required to drive them from an independent source depends simply on the frictional and other losses in each, the amount of current that passes between them, and, consequently, the load on each, depending on the angular displacement in phase of the one in respect to the other. The coupling was graduated in degrees, so that the phase difference between the machines was known. The amount of phase difference necessary for a given current, and, consequently, a given load, was first determined mathematically by coplanar vectors, which have been found generally useful and reliable in this work, and agree with the results obtained. When two machines are rigidly coupled together and are displaced one with respect to the other in phase, one acts as a motor and the other as a dynamo; and to maintain them at a given speed and load it is only necessary to supply from external sources the work lost between the two machines. This being done, the machines can be loaded to any desired amount, and there will be established the same phase relations, reactions, and losses that occur in machines driven under the same load conditions in practice with respect to capacity and inductance. The results of the tests show that when two similar machines are equally excited the phase of current and electromotive force obtaining in the circuit corresponds with close approximation to that of

[1] Philosophical Transactions of the Royal Society, vol. clxxxvii.

[2] *Ibid*, vol. clxxvii. p. 347.

an alternating-current dynamo running on a non-inductive load. The range of the tests, however, is varied considerably, so that the efficiency of the machinery has been determined under conditions corresponding both to a highly inductive load and to a load having a very sensible capacity.

A diagram of the connections is shown in *Fig. 1.* In the main circuit there were two complete self-contained sets of apparatus for the test, one consisting of an ampere-balance, a watt-balance, and an electro-static voltmeter; and the other, which may be called the

Fig. 1.

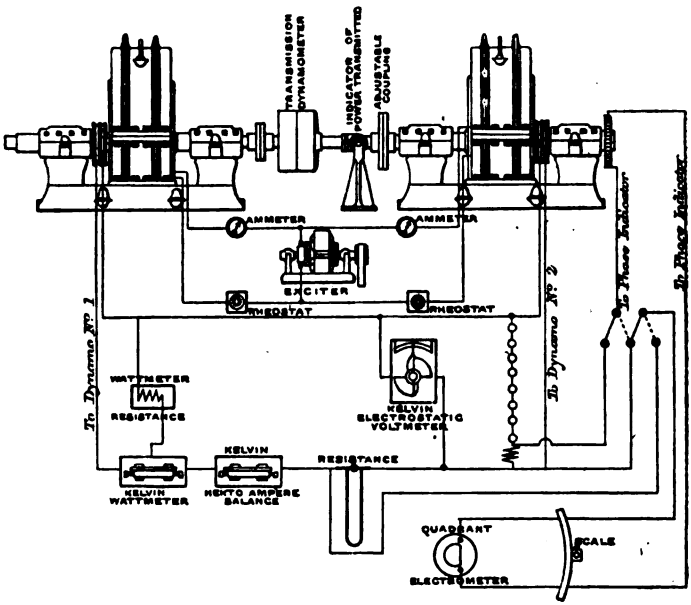


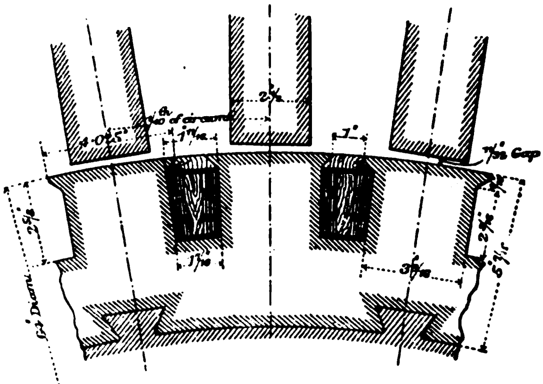
Diagram of the Connections for the Tests.

interrupted-contact set, consisting of a resistance in series with the main circuit and the shunt-resistance across it, an interrupted contact-disk on the end of the shaft, and a quadrant electrometer. The first is the more practical, economical, and direct method. The second method is, on the other hand, susceptible of great refinement and shows the nature of the curves of current and electromotive force and the effect of the reactions in the armature upon the shape of the curves. It, however, entails great labour in observation, plotting, integrating, obtaining constants and calculating tables, yet it is advisable that this method should be used for

a new type of machine when the general characteristics, common to all, can be obtained, such as the form of the electromotive-force curve, the influence of the reactions upon the form of this curve, depending in fact upon the ratio of pole-arc to pitch, the number and shape of the tooth or teeth. After that the more direct method will tell all the properties peculiar to the particular machine under test. In this case both methods were used as a check one upon the other.

The two machines tested were constructed by the General Electric Company of the United States for the British Thomson-Houston Company, to be installed in the generating-station of the City of London Electric Lighting Company, Bankside. The out-

Fig. 2.



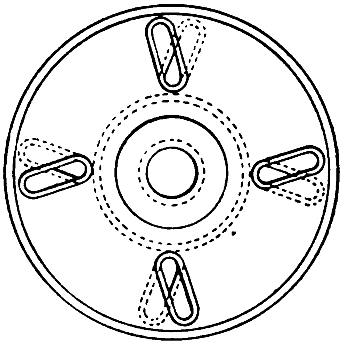
Scale, 2 inches = 1 foot.

CROSS-SECTION THROUGH THE ARMATURE-PROJECTIONS AND POLES.

put is 385 kilowatts, the speed 300 revolutions per minute, and the potential at full load 2,200 volts. The field-magnet system has forty poles, and consists of a cast-iron yoke holding magnet-cores of laminated sheet-iron, the yoke being cast with the magnet-cores in position. The ratio of the pole-arc to the pitch is 0·5. The coil consists of one hundred and thirty turns and is supported by a brass flange. The coils are arranged in two sets of twenty. The resistance of the two halves of the field in parallel is 1,378 ohms at 20° C. The armature consists of a laminated core of iron 0·014 inch thick fixed on a cast-iron spider. The armature has forty T-shaped projections, each carrying a coil of six turns. Its total resistance is 0·1105 ohm at 20° C. The general arrangement of the armature projections and the poles is shown in *Fig. 2.*

The two machines were carefully aligned upon a large surface-plate and connected by the adjustable coupling. That part of the coupling fixed to the one machine has four slots inclined at an angle to the radial direction, and that fixed to the other machine has corresponding slots inclined by the same amount in the opposite direction. The centre lines of the slots, *Fig. 3*, are tangents to a circle about 8 inches in diameter, having its centre in the axis of the shaft. By this arrangement one armature can be advanced relatively to the other by a distance of 5 inches measured on the periphery, which, as the pitch on the periphery of the armature measured 5 inches, corresponded to a phase variation of 180°, or one-half of a complete period. If, in addition, the field of one is reversed, a total phase relation of one complete period is obtained. The position of one armature relatively to the other was determined by means of scales glued on the peripheries of the armatures and fixed to corresponding points, with respect to the armature-coils, and readings taken with reference to corresponding marks on the field-magnet poles. The scales were long enough to cover five poles, so that a fair average was arrived at. As a check upon these readings and as a convenient reference in setting, parts of the peripheries of the two sections of the coupling were marked in degrees, starting from a common zero obtained by careful alignment of the two armatures, with respect to the field-magnets, and to each other.

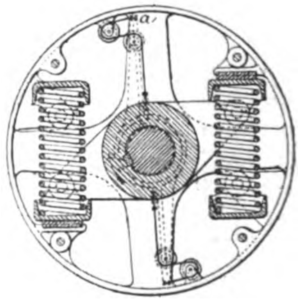
Fig. 3.



The dynamometer, *Figs. 4* and *4a*, through which the power was transmitted to the shafting of the two machines coupled together, was designed by the Author in consultation with Dr. Hopkinson, and proved thoroughly reliable and very sensitive. It is a combination of a pulley or sheave, free to rotate on the shaft within the limits of compression of the springs. The power is transmitted from the belt to the shaft through these springs acting on an arm of 12 inches upon a lever fixed to the shaft. The amount of turning of the pulley, with respect to the shaft, is a measure of the compression of the springs, and therefore of the torque applied to the shaft. To indicate this angular position the shaft has fixed to it within the pulley an auxiliary double lever, to the ends of

which are fixed the ends of the two steel wires. These first pass from the end of the lever round a small sheave fixed to the inner periphery of the pulley, and then to a sheave on the lever, which deflects the wire radially along this lever towards the shaft. It then passes round a sheave on the hub of the lever, which deflects the wire parallel to the shaft; then on to a collar which is free to travel lengthwise along the shaft, but not free to rotate relatively to the shaft. Upon this collar is mounted another, free to rotate, but not to move longitudinally, with respect to the first collar, and it is thereby constrained to travel backwards and forwards along the shaft with the first collar, according to the angular positions of the pulley and lever or according to the power transmitted. This linear motion along the shaft is converted to a circular motion by attaching wires to the second collar passing around small sheaves mounted on brackets, separate from the machine, the motion being multiplied by means of an index and read off on a degree scale. The scale was graduated by clamping a piece of canvas on the pulley, attaching weights to the free end and reading off the corresponding deflections on the degree scale referred to, which, when plotted to correspond with the weights, formed an equivalent to a stress-strain diagram. A power curve was thus deduced for a speed of 300 revolutions per minute. The two curves, *Fig. 5*, give the activity in horse-power and in kilowatts per degree on the dynamometer-dial for 300 revolutions per minute. During the test all readings were taken as nearly as possible at this speed, as the component losses, of which the dynamometer reading is the sum, are functions of different orders of the speed. It was, however, not found possible to adhere strictly to a uniform speed; still, as the more important loss varies with the speed, the error in correcting proportionally to the speed was not great, say, for a difference of 1 per cent. or 2 per cent. Greater weight was given to those readings which were obtained at a speed of 300 revolutions.

Fig. 4.



Cross section.

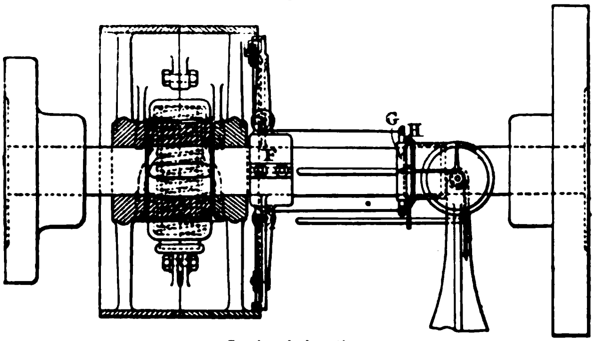
TRANSMISSION DYNAMOMETER.

The first quantity to be measured was the loss through friction of the bearings, and the air-resistance of the coupled machines. At a speed of 300 revolutions per minute, the dynamometer read

40°, which corresponds to a transmitted power of 3,000 watts. This requires care in observing, as the slightest change in speed means a positive or negative inertia factor.

The saturation curves, *Fig. 6*, were next determined for each machine separately, and the dynamometer readings taken at the same time from these observations give also the curves of armature losses with field current, *Fig. 7*, and the armature losses with potential-difference on open circuit, *Fig. 8*, for a speed of 300 revolutions per minute, corresponding to 100 periods per second. The last two sets include 1,500 watts for friction of the bearings and air-resistance, one-half the value obtained in the first observation. This quantity is assumed to be constant, but it is only known when the machine is not excited. The remaining losses consist of

Fig. 4a.



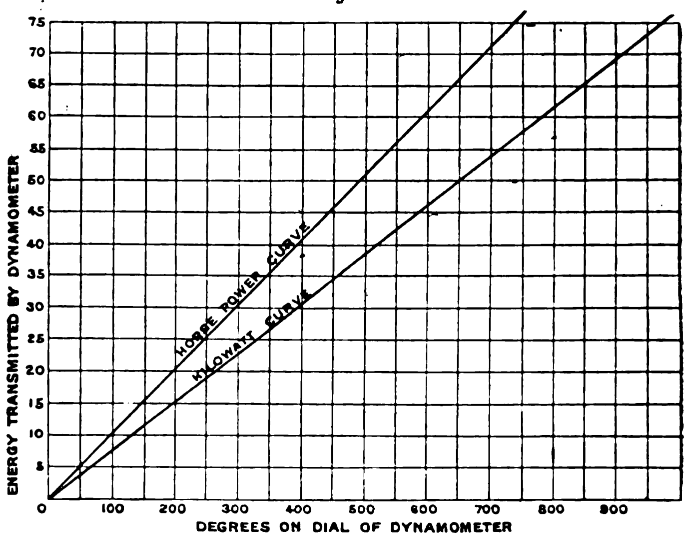
Sectional elevation.

TRANSMISSION DYNAMOMETER.

hysteresis, eddy current loss and losses incidental to the varying reluctance of the magnetic circuit.

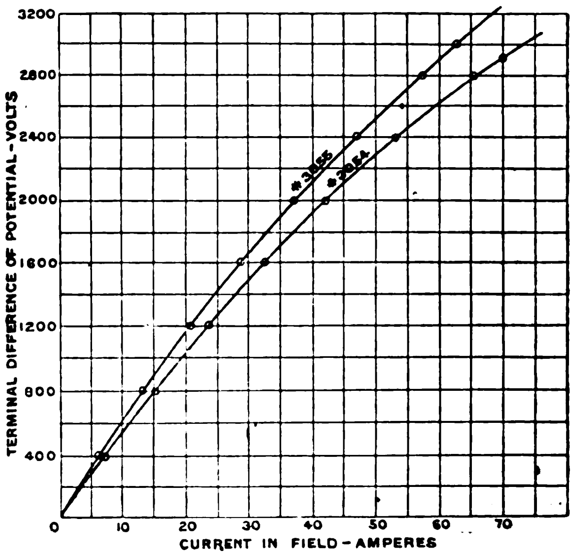
The machines were next coupled together electrically in four different relations corresponding to an exchange of power between the machines equal to full load, three-quarter load, half-load, and quarter-load of either machine; and three sets of observations were taken in each position, one with normal excitation on each machine, another with the excitation of generator above and motor below, and the third with the generator below and motor above, the normal excitation. Readings were taken on the watt-meter, ampere-balance, and voltmeter, and instantaneous values were taken of the current and potential difference on the terminals. In each case about twenty observations were made to construct the curves, Figs. 9–18, Plate 6. In one case only were the open-circuit

Fig. 5.



SCALE OF POWER TRANSMITTED BY THE DYNAMOMETER AT 300 REVOLUTIONS PER MINUTE.

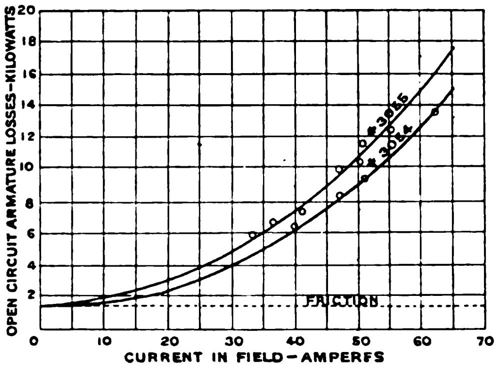
Fig. 6.



SATURATION CURVES AT 300 REVOLUTIONS PER MINUTE.

potential-differences taken directly throughout, this being sufficient to establish the form of the curve and to locate the two potential differences, and to compare their determined positions with the measurements on the coupling. How near this was made to accord

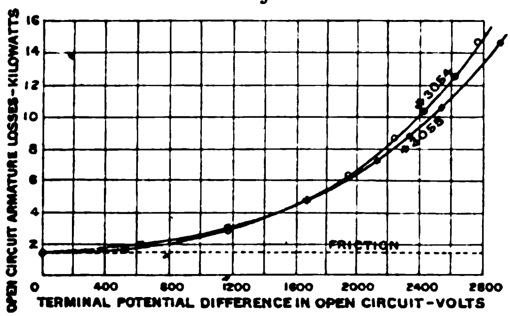
Fig. 7.



CURVES OF ARMATURE LOSSES WITH FIELD-CURRENTS ON OPEN CIRCUIT AT 300 REVOLUTIONS PER MINUTE.

can be seen by reference to Figs. 16–18, Plate 6, in which the curves E_g, E_m, representing the impressed and counter electromotive-forces of generator and motor, cross the zero line 71° or 72° apart. The angular positions of the armature differed by 2·01 inches on the scales laid on their periphery. The mean difference between

Fig. 8.



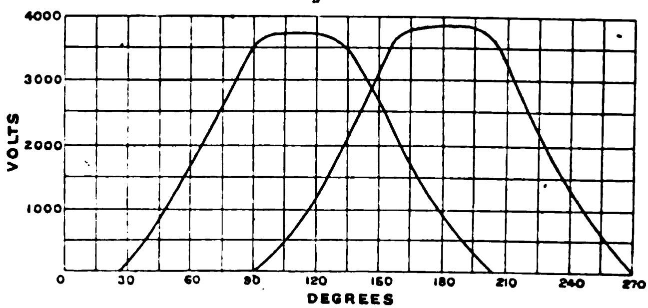
CURVES OF ARMATURE LOSSES WITH TERMINAL POTENTIAL DIFFERENCES AT 300 REVOLUTIONS PER MINUTE.

the poles was 5·01 inches, corresponding as nearly as possible to 72° difference of phase. The terminal potential-difference curve of each machine on open circuit is plotted separately, *Fig. 19*, so that the characteristic of each may be observed.

In the diagrams, Figs. 9–18, Plate 6, E_g represents the impressed

electromotive-force of the generator; E_m the counter electromotive-force of the motor; and "e" represents the effective electromotive-force of both motor and generator. Actually "e" is the curve of instantaneous values of the terminal potential-difference on the generator, but the correction for the generator armature-resistance on the one hand, and for the motor armature-resistance plus the resistance of the connections on the other, are inappreciable, so that the same curve "e" stands for the effective electromotive-force of both machines. The curve marked $\int e\, d\, t$ is the integral curve of "e"; $\int E_g\, d\, t$ the integral curve of E_g; and $\int E_m\, d\, t$ the integral curve of E_m. As shown by Dr. Hopkinson in the Papers referred to, were it not for the effect of the current in the armature, the

Fig. 19.



TERMINAL POTENTIAL-DIFFERENCE CURVES ON OPEN CIRCUIT, SPEED, 300 REVOLUTIONS PER MINUTE.

integral curves should cross at the instant that the current is zero, as implied in the equation for $x = 0$:—

$$\int E\, d\, t = \int R\, i\, d\, t + \int L \frac{d\, i}{d\, t} d\, t.$$

The difference therefore of the two integral curves at the instant when the current is zero, is a measure of that effect of the armature current upon the field which is not accompanied by a corresponding displacement of current relatively to the electromotive-force. The diagrams afford the means of measuring this effect in percentage of the total flux for various effective current values and various phase relations. They show the nature of the effect of the current in diminishing the effective ampere-turns on the field-magnets, and, to some extent the magnitude of the effect; for instance, in Fig. 16, E_1, the phase relations are nearest those of non-inductive load conditions, the difference between $\int E_g\, d\, t$ and $\int e\, d\, t$ is $0 \cdot 15 \times 10^6$, and the maximum flux is $2 \cdot 55 \times 10^6$. The percentage increase in the flux necessary to overcome the effect of

the current of 177·8 amperes in the armature upon the total magnetizing force in the phase relation indicated is approximately 6 per cent. of the maximum value. The E_2 and E_3 curves, Figs. 17 and 18, however, seem to agree that this result is too low, and that the result is nearer 7 per cent., for, in these cases, the percentage is greater, and at the same time the current is more nearly in phase with the impressed electromotive-force. Comparing this group with another group C, say, where the currents in the armature are smaller, the difference is at once apparent. Comparing C, in which the phase relations approximately correspond with group E, it will be seen that the increase necessary in the flux is 3·2 per cent. For this purpose set A is ill-conditioned, as the errors incidental to the plotting are greater than the difference sought for.

The difference in the integral curves at the instant when the current is zero, together with the dynamometer readings, form the basis of the analysis of the reaction of the current, in so far as it affects the core losses in the armature and the field structure. The whole action of the current in the armature may be summarized as follows:—

1. Reaction in the electro-magnetic field accompanied by displacement, expressed by the equation, $E = R x + L \frac{d x}{d t}$.

2. Reaction of current on the field not accompanied by displacement of current, an effect represented by losses through induced current in the field-magnet winding, core and yoke.

The following is the method of analyzing the second effect. It will be sufficient to refer to one set of curves only, thus, take Fig. 16, E_1, the total flux in the armature of the generator necessary to fulfil the conditions 1 and 2 over that necessary to fulfil the conditions in 1 is greater by 6 per cent.; the density is greater and therefore the increase in hysteresis loss and eddy currents may be calculated. Further, from these two values of the total flux is obtained two impressed electromotive-force values, one of which must fulfil condition 1 and can be verified by a polar diagram, and then by referring to *Fig. 8* the corresponding losses are obtained, and the difference gives the increased losses accompanying the increased flux-density. A further reference to the saturation curves and the corresponding field current, together with the resistance of the field-coils, gives the increased $C^2 R$ losses in the field winding. Next the power absorbed is compared with the open-circuit loss for the corresponding impressed electromotive-force of the generator, the difference giving the losses through induced current in the field-

magnet structure, in this instance due to a current of 177·8 amperes in the armature with a phase difference of 28°. The loss from increased flux-density, hysteresis and eddy currents, is 11 kilowatts and the loss through induced currents is 10 kilowatts. The magnitude of this quantity is readily understood when it is borne in mind that a current of a certain periodicity in a revolving armature induces currents of twice that period in a stationary field; in fact, the whole effect of the current, as regards the field-magnet, may be regarded, for practical purposes, as that of a fixed vector, which when compounded with the field ampere-turns gives the effective ampere-turns and a vector of equal magnitude rotating at double periodic turns of the current. The amount of compounding in the first case depends upon the phase relation of current and electromotive-force; the effect of the phase relation upon the latter does not seem to be of so much importance.

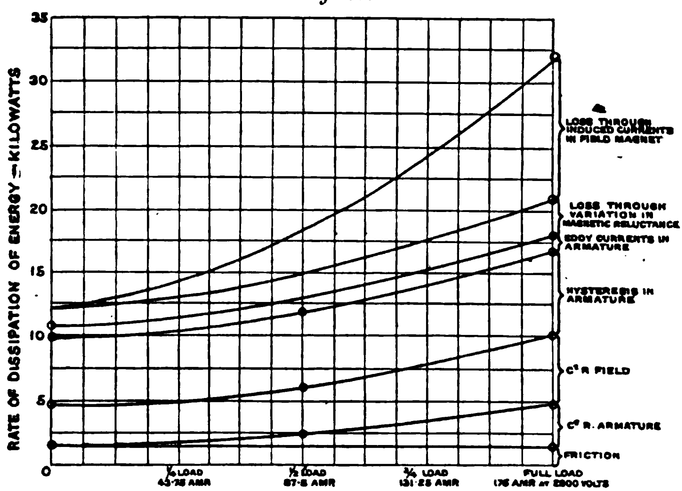
The following Table gives the total loss by induced currents in the field-magnet, in the coupled generator and motor in different phase relations, and for different currents the result varying approximately as the square of the current. The results of the tests are shown in Table I of the Appendix, and give the losses at about quarter, half, three-quarters and full load under three conditions of phase relation of current and electromotive-force indicated by the relative values of the energy dissipated in the fields. Those values which correspond to the higher power factor in the Table, or to coincidence of current and electromotive force in the Figs., may be taken as corresponding to a non-inductive load. It will be seen that the phase relation of armatures, and consequently impressed and counter electromotive-force, remains unaltered under any one letter, such as A, B, &c. The phase relation of the potential-difference terminal D P and current is altered by varying the field-current to an extent indicated by item (*b*). The three conditions are placed under headings such as A_1, A_2 and A_3 for Table I. In item 10, an average value is obtained for both generator and motor by the method of taking half the total number of watts absorbed by the system, less half the known number of watts. This is obviously not always the case, as the impressed electromotive-force of the generator need not be equal to the counter electromotive-force of the motor, neither are they equal in any of these tests.

Curves.	Current in System.	Loss by Induced Currents in Generator and Motor.
	Amperes.	Kilowatts.
E_1	177·8	21
C_1	126·4	10·56
B_1	84·2	5·82

The result of halving the total losses, other than the armature-

winding and field-winding losses, affects the efficiencies of the generator and motor, making the motor efficiency less than the generator efficiency, in spite of the fact that the effect of the current in the field, in these cases, is such as to diminish the $C^2 R$ losses in the field for the same counter electromotive-force. In Table II, which is a summary of this analysis, and also in the curves, *Fig. 20*, this has been done by halving that part of the total loss which is approximately the same for two equal machines, and apportioning the rest in proportion of the impressed and counter electromotive-force. Bearing and wind friction is in this case assumed constant for all loads. Table II gives the allocation of the losses in alternator No. 3,054 in percentage for full non-

Fig. 20.



Potential-difference, 2,200 volts; speed, 300 revolutions per minute.

ALLOCATION OF LOSSES IN MACHINE No. 3054, ON NON-INDUCTIVE LOAD.

inductive load, three-quarter load, half load and quarter load, and one-tenth load. These have been deduced not only from the coupled tests but in part from direct observation of instantaneous values of current and potential difference on a water rheostat. By means of this Table the curves of efficiency can be predicted with fair accuracy for this type of dynamo. The definition of type must cover the shape and number of armature projections, the ratio of the pole arc to the pitch, and the maximum armature reaction, upon which the items 8 and 10 principally depend.

The Paper is accompanied by twenty-one drawings, from which Plate 6 and the *Figs.* in the text have been prepared.

APPEN

TABLE I.—GENERATOR AND MOTOR COMBINATION TEST, SHOWING ALLOCATION OF

—	A_1	A_2	A_3
a. Phase-difference between armatures . degrees	17·7	17·7	17·7
b. Power-factor	0·9723	0·6691	0·8910
1. Power given out by generator in kilowatts (by watt-meter)	93·73	89·22	93·03
2. Power given to motor . . . . kilowatts	93 5	89·00	92·8
3. ,, dissipated in generator-armature ,,	0·21	0·298	0·37
4. ,, ,, ,, motor-armature . . ,,	0·21	0·298	0·37
5. ,, ,, ,, generator magnet-winding ,,	2·93	2·35	3·9
6. ,, ,, ,, motor ,, ,, ,,	2·58	3·19	1·81
7. ,, ,, ,, connections . . . ,,	0·23	0·22	0·23
8. ,, absorbed by combination through belt ,,	22 7	21·9	22·6
9. Total electrical power developed in generator = Nos. 1 + 3	93·94	99·52	93·4
10. Half power absorbed by system, less half known power = ½ {No. 8 − (Nos. 3 + 4 + 7)} . . .	10·90	10·49	10·81
11. Total power given to generator = Nos. 5 + 9 + 10	107·85	102·36	108·12
12. Percentage efficiency of generator = $\frac{\text{No. 1}}{\text{No. 11}}$ . .	87·04	87·25	86·11
13. ,, loss in generator-armature	0·194	0·291	0·340
14. ,, ,, generator magnet-winding. .	2·72	2·29	3·61
15. ,, sum of all other losses in generator .	10·05	10·17	9·94
16. ,, efficiency of generator-armature = $\frac{\text{No. 1}}{\text{Nos. 9 + 10}}$	89·52	89·21	89·20
17. ,, ,, motor = $\frac{\text{Nos. 9 + 10 − 8}}{\text{Nos. 2 + 6}}$ . .	85·6	84·83	86·27
18. ,, loss in motor-armature	0·22	0·323	0·39
19. ,, ,, motor magnet-winding. . .	2·68	3·46	1·93
20. ,, sum of all other losses in motor . .	11·68	11·39	11·43
21. ,, efficiency of motor-armature = $\frac{\text{Nos. 9 + 10 − 8}}{\text{No. 2}}$	88·0	87·83	87·95

DIX.

LOSSES IN THE TWO MACHINES (No. 3,054 AS GENERATOR AND No. 3,055 AS MOTOR).

B_1	B_2	B_3	C_1	C_2	C_3	E_1	E_2	E_3
36·2	36·2	36·2	51·9	51·9	51·9	71·6	71·6	71·6
0·9890	0·8090	0·9659	0·9877	0·8481	0·9877	0·9903	0·9336	0·9613
171·13	159·3	175·82	266·1	258·24	266·97	382·0	376·0	372·0
170·7	158·9	175·4	265·5	257·6	266·3	381·0	375·0	371·0
0·78	0·89	0·93	1·77	1·91	1·92	3·5	3·52	3·36
0·78	0·89	0·93	1·77	1·91	1·92	3·5	3 52	3·36
3·2	2·25	4·52	3·98	2·8	5·57	5·25	4·175	4·37
2·58	3·6	2·11	3·14	4·55	2·44	3·66	5·13	4·3
0·43	0·40	0·42	1·00	0·64	0·67	1·00	1·00	1·00
25·9	26·2	26·35	36·4	37·1	37·25	54·6	54·25	50·75
171·91	160·19	176·75	267·87	260·15	268·89	385·5	379·52	375·36
11·96	12·01	12·04	16·13	16·32	16·37	23·3	23·11	21·52
187·07	174·45	193·31	287·98	279·27	290·83	414·05	406·81	401·25
91·48	91·32	90·95	92·5	92·5	91·75	92·2	92·4	92·75
0·42	0·51	0·48	0·62	0 68	0·66	0·845	0·866	0·837
1·71	1·29	2·34	1·38	1·00	1·99	1·27	1·028	1·09
6·39	6·88	6·23	5·5	5·82	5·60	5·685	5·706	5·32
93·07	92·51	93·13	93·7	93·4	93·68	93·4	93·4	93·7
91·16	90·00	91·51	92·1	91·31	92·2	92·00	91·4	92·3
0·45	0·55	0·52	0·659	0·771	0·714	0·91	0·922	0·896
1·49	2·22	1·19	1·176	1·73	0·908	0·952	1·342	1·145
6 90	7·23	6·78	6·065	6·19	6·18	6·14	6·34	5·66
92·54	91·89	92·61	93·2	92·9	93·23	93·00	93·00	93·3

TABLE II.—LOSSES IN ALTERNATOR NO. 3,054, WORKING ON A NON-INDUCTIVE LOAD.—PERCENTAGES OF TOTAL POWER.

——		Full Load.	Three-quarter Load.	Half Load.	Quarter Load.	One-tenth Load.	No Load.
Total power delivered at terminals	kilo-watts	385·0	288·75	192·5	96·25	38·5	0
Current	amperes	175·0	131·25	87·5	43·75	17·5	0
Potential difference on terminals	volts	2,200	2,200	2,200	2,200	2,200	2,200
Friction (all sources)	per cent.	0·36	0·48	0·71	1·36	2·94	12·5
Field winding	,,	1·272	1·375	1·66	2·98	6·26	25·9
Hysteresis in armature	,,	1·62	2·015	2·8	4·98	10·37	44·0
Eddy in armature	,,	0·288	0·415	0·544	0·905	1·75	5·85
Variation of magnetic reluctance	,,	0·696	0·767	0·946	1·45	2·64	11·75
Armature winding	,,	0·816	0·608	0·426	0·226	0·196	0
Reaction of current in armature on magnet frame	,,	2·645	2·11	1·66	1·175	0·88	0
		7·697	7·71	8·746	13·076	25·026	100·0
Efficiency of generator	,,	92·31	92·29	91·25	86·93	74·97	0
Total power given to generator	kilo-watts	417·0	313·0	211·0	110·5	51·1	12·0

(*Paper No. 2940.*)

"The Harbour of Algoa Bay, Cape Colony."

By Robert Henry Hammersley Heenan, M. Inst. C.E.

In less than 10 years the territories known as Mashonaland, Matabeleland, and Bechuanaland, equal in extent to over 500,000 square miles, have been added to the British Empire in the Hinterland of South Africa. Within the same period the Witwatersrand in the South African Republic has developed the most extensive goldfields in the world, and the spot where Johannesburg now stands was 10 years ago bare Veldt. At present it contains a population of about 60,000, with public and private buildings of palatial character, and is served by all the appliances and conveniences of modern discovery and invention.

The opening of this vast region and the richness of the mines of Johannesburg have created a trade for which the ports of Algoa Bay (Port Elizabeth), East London, Natal, and Delagoa Bay, have for some time keenly competed. The geographical positions of both Natal and Delagoa Bay are much more favourable in relation to the Transvaal than either East London or Algoa Bay, the distances from Johannesburg being:—Algoa Bay, 715 miles; East London, 666 miles; Natal (Durban), 479 miles; and Delagoa Bay, 397 miles. There are, however, other important factors, such as the curves and gradients on the railways connecting the various harbours with the interior, expeditious landing and despatch of cargo, which, if they do not turn the scale in favour of Algoa Bay, at all events place it in a position to compete on equal terms with the other ports.

Since 1820 Algoa Bay has been the principal port of the Eastern Province of Cape Colony, and for many years vessels anchored there, discharged into sailing barges brought up to a warp secured to the shore, and hauled along it until they were beached in 2 feet or 3 feet of water; the cargo was then carried ashore by Kaffirs, or hauled up by tackle. In this primitive manner a trade of about 200,000 tons per annum was for years conducted; in fact, the greater portion of the material for Kimberley, and a

large quantity of the machinery required for the diamond mines, was landed in this way. Small timber jetties were constructed, but in 1881–82 they gave place to iron fendered quays, equipped with lines of rails and steam-cranes. Even after they were completed it was long before the various landing and shipping companies availed themselves of the advantages of the improved accommodation.

The works carried out between 1876 and 1882 by Mr. William Shield,[1] M. Inst. C.E., under the directions of the late Sir John Coode, Past-President Inst. C.E., included the reclamation of a considerable area of the foreshore, by the construction of a sea-wall, and the erection of two jetties, 900 feet and 840 feet long respectively, and each 64 feet wide. For some years this accommodation proved sufficient for the requirements of the port, but as the volume of trade gradually increased the traffic became blocked at frequent intervals. The north jetty has accordingly been lengthened by 240 feet, and widened by 24 feet; and the width of the approach viaduct has been increased so that a portion might be railed off to provide a safe gangway for the convenience of the public going to and coming from the landing stages, *Fig. 1.* The new portion of the structure has been constructed of sufficient strength to render it safe for vessels of suitable draught

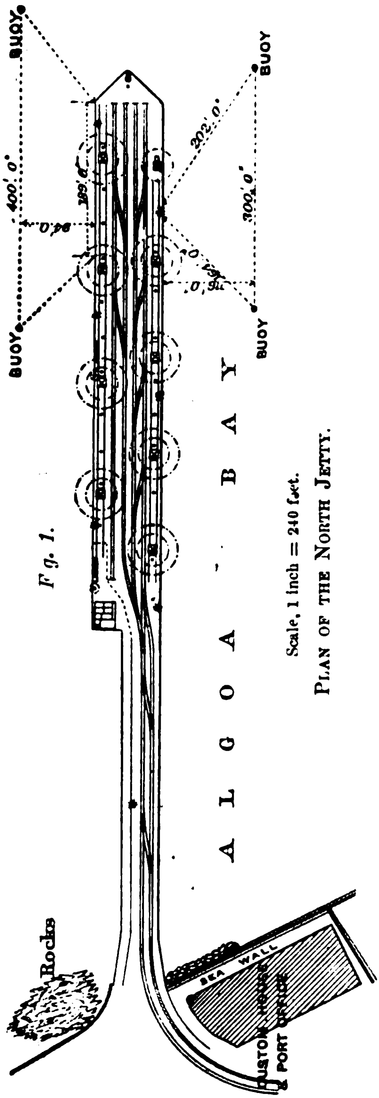


Fig. 1.

Scale, 1 inch = 240 feet.

PLAN OF THE NORTH JETTY.

[1] Minutes of Proceedings Inst. C.E., vol. lxxxviii. p. 359.

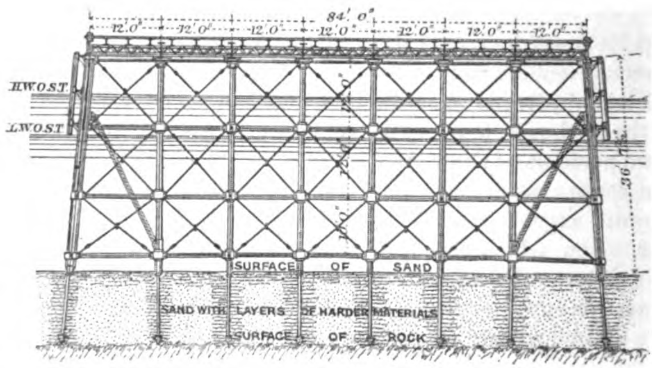
to discharge and take in cargo and ballast alongside, when the sea is sufficiently smooth, as it frequently is, especially during the winter season, between May and September. The depth of water immediately under both jetties was found to have been gradually increasing, in the case of the north jetty to such an extent as to seriously interfere with the stability of the structure. This deepening was the result of a churning action of the waves between the piles, caused by the free run of the tide having been obstructed by marine growth at the junctions of the diagonal tie-rods. These obstructions not only accounted for the scouring action, but, as they presented a large resisting area to the waves, they caused perceptible vibrations in the jetties during heavy weather. While this growth was being removed to examine the connections, the bolts were found in many cases to be almost worn through. The greenheart piles, fenders, and walings, which had been in use for only 8 years, were found to have been attacked in several instances by the *teredo*; and at almost every scarf, and where the vertical fenders were cleated to the walings, the *limnoria* had completely destroyed the timber under the surface, and in some cases the fenders could readily be moved by the hand. Oxidation on some portions of the work, and especially on the girders exposed to the south-east winds, had been very active. The decking of the south jetty originally consisted of 4-inch creosoted Baltic timber, upon which the lines of rails were fixed. In order to permit of cargo being more easily moved about in barrows, the decking was subsequently sheathed over flush with the rails, with 3-inch ordinary deals; in a few years this sheathing had become so rotten in places that it had to be removed, and it was found that the underlying creosoted timber was affected in the same way, although not to the same extent. Similar decking on the south jetty, laid down in 1882 but which had not been sheathed, remains perfectly sound. Four lines of rails have been laid down, beside those required for cranes, in order that, by means of a luffing jib, each crane might be made to plumb four railway trucks, two on each road.

The general design of the extension, *Fig.* 2, was similar to that of the original work, with the exception that the outer piles were made stronger and stiffer, and of the cross section shown in *Figs.* 3, and were further strengthened by struts abutting against the second row of piles in a diagonal direction. The greenheart walings and fenders were dispensed with, and 12-inch H-bars substituted for the former, and 12-inch channel-bars filled in with soft wood, projecting slightly, for the latter.

The projecting hook, which was introduced at the end of the original work, and still exists in the south jetty,[1] was not repeated, for although it afforded some shelter, and to a certain extent combed down the sea in bad weather, it was found to seriously interfere with the movements of tugs, launches, and lighters. The diameter of the screws was reduced from 3 feet 6 inches to 2 feet 5 inches to diminish the difficulty in driving them.

The contract for the ironwork was let to the Thames Iron and Ship-building Company, Limited, and on the arrival of the first shipment in August, 1892, the work of erection commenced, and the last pile was fixed in position on the 13th February, 1894. The plant was of a simple character, an ordinary counterpoised

Fig. 2.



Scale, $\frac{1}{32}$ inch = 1 foot.

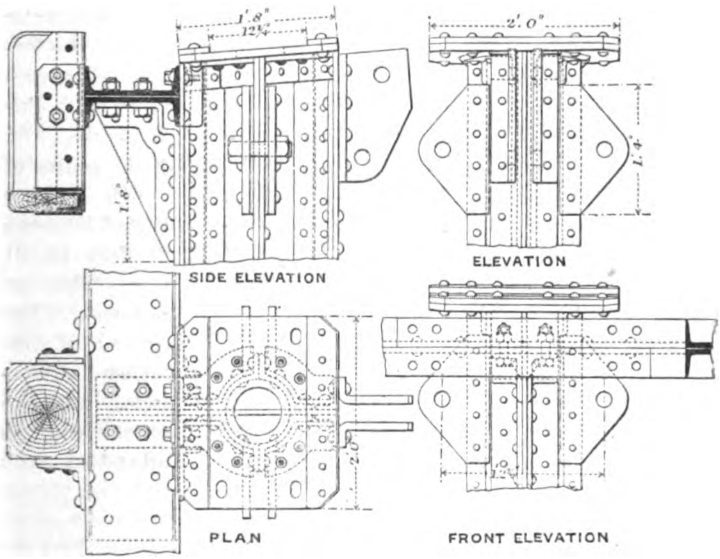
CROSS SECTION OF THE NORTH JETTY EXTENSION.

traveller, half the width of the jetty and having a 15-foot overhang, being used instead of staging, and from the end of the traveller the piles were placed in position by means of a piling engine. The piles were screwed by steam-power, and this was the most troublesome portion of the work, as the strain necessary to penetrate a thin layer of hard material, just before the rock was reached, proved as great as the piles would safely stand, and in one instance the dolley keys were sheared off. In many cases the piles showed a tendency to become "cork-screwed" under the excessive strain that had to be exerted in driving them the last

[1] Minutes of Proceedings Inst. C.E., vol. lxxxviii., Fig. 7, Plate 3.

foot or so, and it is more than probable that, had a screw of larger diameter been adopted, the rock in some cases could not have been reached. The under-water work was performed by divers who worked in pairs, and, as is usual, formed a heavy item of the expenditure. As it was impracticable to ascertain the exact length the piles should be until they were screwed down, they were purposely left long, and were cut when the length required was known. In the old work this was performed by a specially designed machine, somewhat resembling a lathe; but a 32-inch

Fig. 3.



Scale, ¼ inch = 1 foot.

OUTER-PILE CAP.

Hetherington saw was used with unqualified success. It worked at a speed of five revolutions per minute, cutting through the large piles in 30 minutes, and the smaller in 25 minutes. A series of trials showed that it will cut through steel 7 inches in diameter at the rate of 1·04 inch per minute. The saws are sharpened by a Hill machine, with an automatic feed. The piles when fixed in position were filled with Portland-cement mortar, with 1 part of cement to 2 parts of sand. In all cases the girders were bedded on ½-inch pieces of teak, cut to fit into the pile-cap.

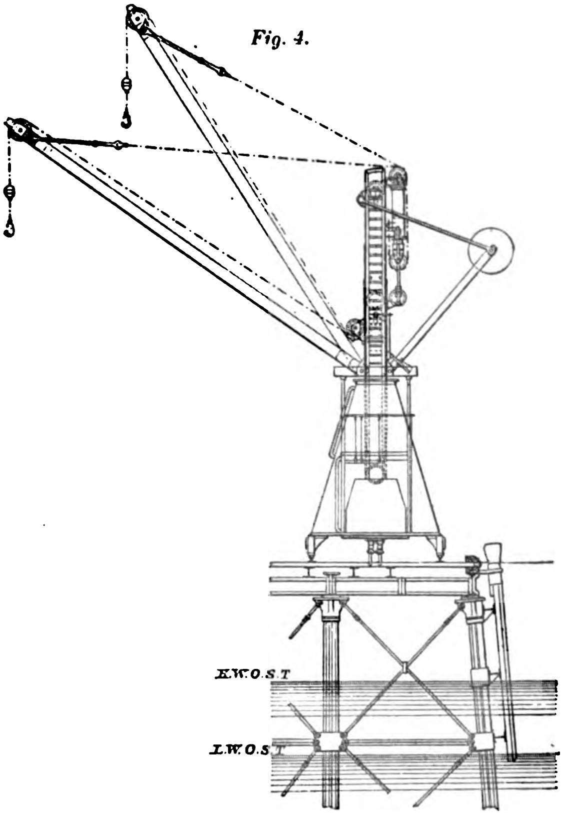
The total cost of the extension and widening was £68,093 7*s.* 7*d.* made up as follows:—

	£	s.	d.
Ironwork delivered f.o.b., London	36,905	17	4
Freight, insurance and landing charges . . .	3,827	17	5
Erection, including plant, painting and decking, and cost of raising loan	27,359	12	1
Total	68,093	6	10

or £1 15*s.* 11*d.* per superficial foot of decking area.

Hydraulic Machinery.—The jetty is now equipped with one 7-ton and eight 2-ton hydraulic cranes, the former being provided with luffing jibs, *Fig.* 4, the radius of which can be varied between 21 feet to 31 feet. This arrangement has proved of immense advantage, as the cranes can be adapted not only to plumb craft of various sizes, but to work over two lines of rails, and thus save much loss of time in shunting, as cargo can be discharged into trucks on No. 2 road while others are being placed in position on No. 1, and *vice versa.* The cranes will discharge on an average 40 tons per hour each, whereas steam-

Fig. 4.



Scale $\frac{1}{16}$ inch = 1 foot.

2-Ton Hydraulic Crane.

cranes of the same lifting-power will scarcely deal with 30 tons. This advantage in favour of the former is due, not only to their having quicker movements, but to the fact that the luffing jibs enable them to command four trucks, whereas the steam-cranes, having a fixed jib, are limited to two. Hydraulic capstans have also been installed for shunting purposes with snatch heads at suitable points.

The pumping-engine house and accumulator tower had to be erected on the reclaimed ground close to the mouth of the Baakens River, and as no hard bottom could be found by boring, the sites of the tower and chimney were excavated to a depth of 10 feet. Pitch-pine piles, between 12 inches and 14 inches square, were then driven to a depth of about 35 feet, and 4 feet apart. Walings 12 inches square were laid on the piles, and a solid mass of concrete was laid 12 inches below the walings, and filled flush with them. Old rails were then laid across close together, and the concrete was brought up in a solid mass to a little above ground-level. The pumping engine is of the ordinary compound type, of 150 HP., made by Sir William Armstrong, Mitchell and Company, the steam being supplied from two steel boilers. As experience has shown the danger of trusting to a single engine where a large volume of trade has to be daily dealt with, a duplicate has been installed. The total cost of the hydraulic plant, including buildings, has been £23,764 0*s.* 4*d.*

The cost of working both steam and hydraulic cranes since May, 1894, is given in the following Table:—

Description of Crane.	Lifting Power.		Lifting Speed.	Slewing Speed, Complete Circle.	Radius.	Cost per Ton of Cargo Landed.
	Tons.	Cwts.	Feet per Sec.	Seconds.	Feet.	*d.*
Hydraulic . . .	2 1	0 5	1·79 4·33	17	21 to 31	2
Steam	2	10	1·08	23	22	4½

From this Table it may appear that the saving effected by the substitution of hydraulic for steam power does not altogether justify the expense incurred; it must, however, be remembered that by means of the luffing jibs of the former, shunting (a very important factor on a confined area) is greatly reduced, and further they can be utilized without loss of time to load or discharge any craft up to 45 feet beam.

Overhead Travelling Cranes.—In consequence of the increasing importations of bulky and heavy machinery for the diamond and

gold fields, a large depositing area had to be provided to the south of the Baakens River, where this class of cargo is unloaded from the trucks by means of powerful overhead travelling cranes, at present worked by hand, and after it has been sorted and examined it is again lifted by the cranes on to the railway wagons, and forwarded to its destination.

Sea-wall and Reclamation Works.—Increased yard and warehouse accommodation having become an urgent necessity it was decided to reclaim the foreshore to the south of the north jetty, involving the construction of a sea-wall or embankment, and also a training-wall at the mouth of the river. The former is open to the full force of the sea, and carries with it deep water as it advances; it is not intended at present to do more than form a rubble bank protected to the seaward by large stones between 4 tons and 6 tons each, interspersed with 3½-ton concrete blocks. An apron and wall will be added when the work has settled. The cost of this embankment, exclusive of concrete blocks, has been about 3*s.* 6*d.* per cubic yard, including the haulage of the material—which has to be conveyed about 1 mile—and all requisite plant.

The concrete blocks are composed of 1 part of Portland cement, 5 of clean quartzite, and 2 of sea sand, and they cost £1 0*s.* 6*d.* per cubic yard, the items being:—

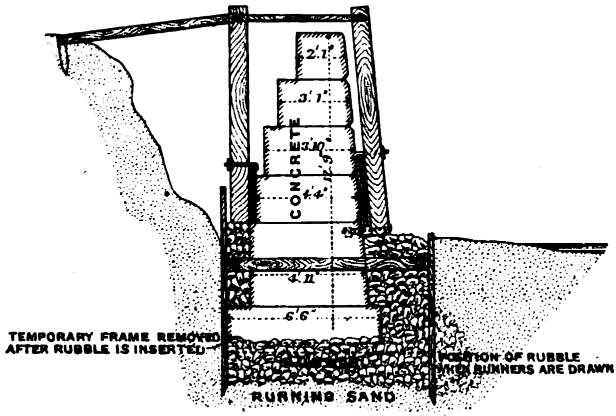
	£	*s.*	*d.*
Stone, including quarrying, breaking and haulage . .	0	5	0
Cement (the cost of cement delivered at the Board's stores is 9*s.* 11*d.* per cask of 375 lbs. net)	0	12	0
Labour	0	3	6
Total . . .	1	0	6

The quarries are close to the works, and stand about 50 feet above them, but in order to obtain an easy gradient, and to insure safety in working, the lines leading to them are about 1 mile in length. The stone is a particularly hard quartzite but much shattered, and so twisted and contorted as to render it almost impossible to follow the planes of stratification. Experience at these quarries showed that (*a*) well trained Kaffirs can drill holes as cheaply as by steam power; (*b*) three men (Kaffirs) drill a 6-foot hole, varying in diameter between 2½ inches at the top and 1½ inch at the bottom, at the average rate of 0·66 foot per hour; (*c*) Roburite and gelignite are more suitable (when it is desirable not to shatter the stones) for blasting than dynamite or gun-powder; (*d*) the most effective charge per foot varies between 4 oz. to 5 oz. of roburite, according to the nature of the

rock; (*e*) Roburite used over a period of 6 months averaged 1 lb. for every 16·54 tons of stone quarried (gelignite has only been recently introduced, and as the quarry varies so much it requires some time to arrive at reliable averages); (*f*) the ratio of stone (varying in size between ½ cwt. and 6 tons) to small rubble is as 0·68 to 1·45. (*g*) The cost of quarrying, including the loading up into wagons and haulage to the works, is for large and for small stone 2*s*. 7*d*. per ton.

Baakens River Retaining-Wall.—The north bank of the river being but badly protected from the heavy floods that occasionally come down, it was found necessary to construct a wall, *Fig. 5*,

Fig. 5.



Scale, ¼ inch = 1 foot.

RETAINING-WALL, BAAKENS RIVER.

from the bridge, in order to secure the valuable buildings in the vicinity. The foundations, however, presented the same difficulty as was experienced at the hydraulic-power house; it was therefore decided to sink as deep as practicable by using 3-inch sheet piling, and to fill in with rubble for 3 feet and bring up the wall in mass concrete.

Screw Moorings.—With the object of preventing the north jetty being subjected to any undue strains or bumpings, by vessels coming alongside, four sets of screw moorings have been laid down in the positions shown in *Fig. 1*. The screws are 3 feet 6 inches in diameter, and great difficulty was experienced in driving them. In one case the 4-inch square steel head upon which the screwing key fits was wrenched off, and as this occurred when the screw

was a little more than half-way down, a dangerous obstruction was left, which is proving difficult to deal with.

The screw moorings were laid down so that vessels might be made fast to them, and allowed to come up to the wharf without actually touching, but they have not proved satisfactory, and when there is any swell, vessels have to be breasted up and made fast to the bollards, which are at times subjected to considerable strains.

Electric Light Installation.—An arc- and glow-lamp installation has been laid down, the former to light the wharves and the depositing grounds, the latter the warehouses and offices. Both dynamos are worked by an Otto gas-engine, of 15 HP. The consumption of gas under varying loads has been noted. The average is 33·83 cubic feet per electrical horse-power developed, and the cost per lamp (Brockie Pell 2,000 C.P. each) is

	d.
Gas and carbons	3·57
Wages and maintenance	2·40
Total cost . . .	5·97 per hour.

Workshops.—With such a large variety of machinery and plant to keep in repair, and expensive works under construction, it has been found necessary to erect new permanent workshops, equipped with the usual tools.

Permanent Way.—All lines of rails are of the same gauge as the Government railways, and are laid with steel rails, 46½ lbs. to the yard. Many of the curves are less than 200 feet radius, and those leading on to the north jetty, over which nine-tenths of the trade of the port passes, are only 180 feet and 171 feet radius respectively. As the trucks used have a rigid wheel-base of 8 feet the wear and tear is very great, both on the rails and rolling stock.

Equipment.—The equipment of the port consists of eight 2-ton hydraulic cranes and one 7-ton hydraulic crane, on the north jetty; four 2-ton steam cranes, one 7-ton steam crane, and one 20-ton hand crane, on the south jetty; three 5-ton overhead cranes, 55 feet span, one 15-ton overhead travelling crane on the depositing ground; five four-wheeled coupled tank locomotives, and two hundred railway trucks, and 2½-ton tip-wagons for use for ballasting ships.

Stores.—The stores for the reception of perishable cargo have a floor area of 97,172 square feet, and an additional 30,000 square feet is about to be provided. The depositing grounds for heavy machinery, coal, &c., cover somewhat more than 13 acres.

The average tonnage of cargo dealt with at the port for the past four years has been—

	Tons.
Imports	343,722
Exports	121,716
Total . . .	465,438

During the twelve months ending 1895, 472 vessels entered the port, having a gross tonnage of 1,326,425.

Works in Contemplation.—As all up-country traffic from the harbour has to pass through the town, no explosives are permitted to be landed on the wharves, consequently this work has to be performed further to the northward, by warping lighters on to the beach, the dynamite, &c., being carried ashore by natives. For these services the boating companies make a charge varying between 7*s.* 6*d.* and 10*s.* per ton, and as the imports are considerable, improved arrangements are demanded. It has been decided to construct an isolated staging in about 12 feet of water, to be connected with the shore by a wire rope-way, terminating in a shed alongside a railway siding, by which means it is estimated that the cost of landing will be reduced by one-half.

For many years the want of a slip for small craft has been felt, and many suggestions have from time to time been made. In 1893 the Author proposed a hydraulic ship-lift, and had drawings prepared; and although the scheme was approved by the Commissioners and Consulting Engineers, it probably will have to be abandoned on the score of expense. Surveys are now being made at the mouth of the Shark's River, and close to the Bird Rock, as it is thought that at either of those places a slip can be constructed, on which craft may be safely brought up when the sea is smooth, which is the case on at least 100 days in the year.

Working Arrangements.—Every charge directly and indirectly connected with the landing and shipping of cargo should be reduced to the lowest point possible; and further, vessels should be rapidly discharged and loaded. It was with these objects in view that the improvements already described have been undertaken, and with the facilities as they now exist, there would be no difficulty in landing 3,000 tons of cargo per day. In consequence, however, of there not being sufficient suitable shed accommodation, the largest tonnage yet dealt with in 1 day did not exceed 2,500 tons.

Before the north jetty was lengthened, widened, and strength-

ened, all cargo was landed by lighters. Now, however, sailing-vessels and small steamers are frequently brought alongside, and discharged directly into railway trucks; but in an open road-stead this can only be done when the sea is moderately smooth. At first, masters of vessels were slow in availing themselves of this advantage, but when it was proved to be safe, and time and money were saved, the number of applications to come alongside rapidly increased. A Clan Line steamer, of 2,400 tons, has come in without difficulty, and discharged a large portion of her cargo without the slightest hitch. With sailing vessels, which have no steam-winches, and are generally insufficiently manned, it is a manifest gain to come up to the wharves; as they are discharged, loaded, and ballasted in as many hours as it would otherwise take them days. When vessels alongside require stone or sand ballast, it is brought down in 2½-ton wagons, which are lifted bodily by a 7-ton crane, placed on deck, and tipped into the hold at the average rate of about 55 tons per hour.

The interest on capital expended on the works is covered by a charge of ⅜ per cent. wharfage dues on the value of all goods exported and imported, which averages 1*s.* 3½*d.* per ton.

Littoral Drift.—The movement of sand in Algoa Bay is similar to that on all other sandy coasts; it "makes up" in calm weather and during off-shore winds, and is broken up during south-east gales, and it is not an unusual occurrence for an accumulation of between 4 feet and 6 fect to pile up on the foreshore in a few days. In a bay where there are no currents excepting those caused by winds and wave action, and where they change their direction so frequently, it becomes almost impossible to estimate what proportion the sand which is carried round the bay bears to that which is drawn out to sea to "make up" again under favourable circumstances. It is generally accepted that there is a constant travel of sand along the coast from west to east, and that it moves round Cape Receife. The largest supply is from the great sand-drift which runs in a south-westerly direction across the Receife peninsula, and which is about 10 miles long, and between 2 miles and 3 miles wide, the dunes varying between 10 feet and 40 feet in height. Within the last 30 years a large portion of the area now occupied by this waste of sand was the site of prosperous agricultural and dairy farms, from which the proprietors derived considerable profit, owing to the nearness of a constant market. But the surrounding scrub was recklessly cut down, and then began the drift of sand, which eventually inundated the whole space, leaving a desert of shifting sand, which was

gradually blown across the peninsula by the prevailing westerly and south-westerly winds. When it reached the shores of the bay cannot be definitely fixed, the evidence on the point being conflicting, but it is certain that for the past 25 years many thousands of tons of sand have been blown into the bay, and carried northwards past the works.

Some years ago the Harbour Board commenced the reclamation of these sand-drifts, and succeeded in cutting off, by means of barricades, the source of supply, and planted a considerable area. The work is now being carried on by the Government under the Forest Department, the Board contributing £1,000 per annum towards the cost. It is estimated that it will take about 20 years to complete. The reclamation is effected by spreading town refuse about 1 inch thick over the sand, and planting it with grasses and various kinds of trees. The refuse is tipped into trucks at two fixed points in the town, and conveyed from there on a railway. The total area of the dunes, which are in some places 200 yards apart, is 9,700 acres, and the cost of reclamation —with convict labour at 1*s.* per day—is £8 per acre, but at present only about 26 acres are reclaimed per month, as the supply of refuse is less than was expected. The following grasses are found most suitable for fixing the sand: *Ehrharta gigantea* (*Pypgrass*), *Priticum junceum* (*trietieum*), *Psamma araenaria;* and the trees that do best are *Acacia-saligna*, *Acacia-pycnantha*, *Acacia-cyclopis*, *Pinus halepensis*, *Casuarina quadrivalis*, *Casuarina Leptoclada*, *Cupressus macrocarpa*, *Hakea suaveolens*, *Robinia pseudacacia.* It is estimated that in ten years the timber and bark will yield a return of £5 per acre, and this expectation is justified by the results of similar works commenced some sixteen years ago in the neighbourhood of Cape Town. This work was undertaken by the Government on the recommendation of Mr. James Storr Lister, Conservator of Forests, who has placed Mr. Thomas B. B. Hare in immediate charge, and to whom the Author is indebted for the above information.

The Paper is accompanied by eleven drawings, from which the *Figs.* in the text have been prepared.

(*Paper No. 3004.*)

"Greenock Harbour."

By WALTER ROBERT KINIPPLE, M. Inst. C.E.

GREENOCK harbour, situated on the south side of the Clyde, close to its junction with the deep water of the estuary, possesses a considerable depth of water, in a sheltered position, with a large and well-protected roadstead in front, having good anchorage ground and accommodation with the adjoining Gare Loch for a very large fleet of vessels. These facilities were first utilized about the year 1640, when a dry stone pier was built, which served as a landing-place for fishing and coasting craft, and for vessels trading to Ireland. In 1656 a Customs official, deputed by Cromwell to visit the various ports on the Clyde, reported favourably on the harbour of Greenock and its shipping.

By 1686 the growth of the business of the port, and the accession of foreign trade, rendered the accommodation inadequate; and an extension was resolved upon, consisting of an approximately square harbour, reclaimed from the beach by two piers, with curved outer ends, and affording a depth of 18 feet at high water of spring tides. This harbour, about 11½ acres in area, partially divided by a central jetty, was carried out in 1707–10, at a cost of £5,555. The excavation in the harbour was done by gardeners from Edinburgh, who were then considered the most suitable workmen for the purpose. Quay-walls connecting the shore ends of the two piers and the jetty, were added in 1764. Considerable modifications have been made in the quays surrounding this west harbour, by which the water area has been reduced to about 7½ acres; and it has also been deepened, so that there is now a depth of water at the entrance, over the rails of the travelling bridge, of 26 feet at high water of spring tides, and 20 feet within the harbour, Fig. 1, Plate 7.

In 1785 the graving dock in this harbour was constructed by James Watt at a cost of about £4,000. It is 220 feet long, 50 feet wide at coping level, and 34 feet at floor level; the entrance is feet wide, with a depth of about 10 feet of water on the sill

at high tide. It is now only used for the smallest class of vessels. In 1883 extensive repairs to the floor, entrance, and gates, were carried out, by which the dock was again rendered serviceable. In a previous Paper, the Author has described the method by which he grouted the entrance of this dock with Portland cement, and thereby stopped serious leakages.[1]

The East India harbour was commenced in 1805, by John Rennie, and cost £43,836. The area of the harbour, as originally designed, was about 9 acres; but it was subsequently reduced, by the construction of the east graving dock and widening the quays, to about 6¾ acres, Fig. 1, Plate 7. The length of quayage is about 3,380 lineal feet, and the depth of water is 22 feet at high water of spring tides. In 1818, the construction of the east graving dock, in the south-west corner of the East India harbour, was commenced. It is 356 feet long at floor level, and has an entrance 38 feet wide, with a depth on its sill of 11 feet 10 inches at high water; and it cost £20,000. The side walls and entrance are of masonry faced with sandstone ashlar, and the floor is of timber. This dock has been in constant use since it was finished, and is still in excellent working order. Further harbour extension was provided by the construction, in 1846–50, of the Victoria harbour by Joseph Locke. It is 5½ acres in area, has a length of quayage of 2,350 lineal feet, and a depth of 24 feet at high water of spring tides, Fig. 1, Plate 7. The walls are faced with sandstone ashlar, and are supported by bearing piles in the soft stratum on which they are mostly founded. The cost of this work was over £120,000.

The Albert harbour and Prince's pier were next constructed, by Messrs. Bell and Miller of Glasgow,[2] Fig. 1, Plate 7. The completion of Prince's pier was executed under the Author in 1869 to 1872. The Albert harbour, which is nearly rectangular, encloses an area of about 10¾ acres; it has a length of quayage, including the river frontage, of about 4,230 feet, and a depth of water of 24 feet at high water of spring tides. The quay walls are of rubble and concrete, faced below low water with granite slabs 7 feet square by 24 inches thick, placed between cast-iron double-flanged piles, and above low water with sandstone ashlar 20 inches thick. The cost of these works, including land and sheds, which cost over £50,000, exceeded £250,000. Prince's pier is a timber structure extending 1,206 feet westwards from the west end of the Albert

[1] Minutes of Proceedings Inst. C.E., vol. lxxxvii. pp. 70–71.
[2] *Ibid*, vol. xxii. pp. 423–427.

harbour. The pier is 20 feet wide on the top, and has a depth of water in front of 26 feet at high water. The piles, struts, and diagonal ties are greenheart, and the decking is creosoted fir covered with pitching. About half-way along its front, the firm clay into which the piles were driven dipped so much that piles 96 feet in length were required, formed of two logs fished together, the lower one being pitch pine and the upper greenheart. At the west end of Prince's pier, there is a return end forming a boat harbour, having a quay frontage of about 1,000 feet, 600 feet consisting of greenheart piling and 400 feet of masonry wall. The cost of this work was about £100,000.

The increasing trade of the port soon necessitated further harbour accommodation; and as the esplanade and villa residences at the west end of the town prohibited extension in that direction, extension eastwards was decided upon; and in 1867 the Harbour Trustees acquired the Garvel Park estate of 56½ acres at a cost of £82,000. In 1868 the Author submitted a design for wet and dry docks and tidal harbours on this estate, which was subsequently developed into the more extensive scheme of harbour works described in this Paper; of which a second graving dock, to accommodate the largest vessels afloat, and the extension of two embankments still remain to be carried out.

Garvel Graving Dock.

The dimensions of this dock are as follow:—

Length on floor	635 feet.
Width of timber floor	41 „
„ dock-bottom	70 „
„ dock at coping	80 „
Depth from coping to floor next outer entrance	27 „ 9 inches.
Inclination of bottom	1 in 400.

Outer Entrance.

Width at coping	60 feet 6 inches.
Depth from coping to sill	27 „ 3 „
„ of water on sill at high water spring tides	20 „ 0 „

Intermediate Entrance at Head of Dock.

Width at coping	52 feet.
Depth from coping to sill	25 „ 9 inches.
„ of water on sill at high water spring tides	18 „ 6 „

This dock was constructed 535 feet long on the floor in 1869–72, with a temporary rubble wall across the head; and in 1876,

100 feet were added, together with one of the inverts of the intermediate entrance to form a connection with the proposed second graving dock, Figs. 1 and 2, Plate 7.

The lines of coping and upper altars are maintained unbroken throughout, as a convenience for working the dock; and broad timber slides and easy wide stairs are provided at the head and sides of the dock, to conduce to the safety and comfort of the workmen.

The cross-section of the dock, Fig. 2, Plate 7, with only three altars in the upper 12 feet of the walls, and a vertical wall below, is economical for the accommodation provided. The footways adjoining the side walls form additional floor area, and admit of two vessels, or two lines of vessels, being arranged in the breadth of the dock, more especially if the keel blocks are placed in overlapping lines angular to the centre line of the dock. Thereby every available foot of floor area is utilized; and frequently vessels of a keel length of 750 feet have been docked on a floor 600 feet in length. A high wall, close to the ship's side, has not been attended with insufficiency of light; whilst the saving in cost of side walls and excavation is considerable.

The entrance to this dock, which is closed by the Author's combined travelling caisson and folding bridge, consists of an inner and outer invert, the berth for the caisson between the inverts, and a chamber into which the caisson is hauled back for opening the entrance. This chamber is platformed over with rolled iron joists, having brick arches between them overlaid with granite pitching at quay-level. Immediately outside the outer invert, a platform has been constructed on which the caisson may be placed when it is desired to increase temporarily the length of the dock, or to lay the caisson berth and chamber and the outer invert dry for repairs. This has only been done once since the dock was opened, when no difficulty was experienced in taking out the caisson and placing it against the outer face of the outer invert, and it served its purpose admirably. The side walls are of rubble concrete faced and coped with granite, the rubble being obtained from the site now occupied by the wet dock. The mortar for the rubble was composed of 3 parts of sand, ½ part of mine dust, 1 part of Arden hydraulic lime found near Glasgow, and ½ part of Portland cement. The ashlar and copings are laid with 1 to 1 Portland cement mortar, and pointed with neat cement. The floor of the dock is formed of rubble concrete, faced with 8-inch whinstone pitching, for 14½ feet from each side wall, and of timber in the centre. This concrete consists of 1 part of sand, 1 of broken

stone, $2\frac{1}{2}$ of ballast, $\frac{3}{4}$ of hydraulic lime, and $\frac{1}{4}$ of Portland cement. The central portion of the floor, 41 feet in width, is of American red pine, consisting of three tiers of whole balks bolted together, spaced 4 feet apart centre to centre, filled up solid with concrete, the bottom row 12 inches by 12 inches laid transversely, the next longitudinally, and the top row, 15 inches by 15 inches transversely again, covered at dock-bottom by 6-inch American elm planking.

Arterial drains made of boards and square in section were laid underneath the dock-bottom, and up the backs of the side walls, to carry off any water coming in from the sea or from land springs, and discharge it into the rudder-well, and thus guard the work against water-pressure, Fig. 2, Plate 7. They were formed in lengths of 30 to 50 feet, fished at junctions, perforated at intervals with sixteen $\frac{3}{8}$-inch holes per foot run, and surrounded by porous concrete composed of shingle rolled in a thick grout of cement.

The inner and outer inverts at the main entrance to the dock are constructed of brickwork, built on a cellular substructure of brickwork, filled up with 6 to 1 concrete. There are also brick inverts all along the caisson berth and chamber. The side and wing walls of the entrance are of rubble faced with granite ashlar and whinstone pitchers. The side walls of the caisson chamber are formed with arched recesses of brickwork backed with rubble. The invert and caisson stop quoins are of granite with glossed meeting faces, 12 inches wide, and projecting $\frac{3}{4}$ inch from the body of the quoins and are dowelled together.

The main culvert for filling and emptying the dock is $6\frac{1}{2}$ feet high by 5 feet wide, and on an average it fills the dock with water in twenty minutes. Two centrifugal pumps empty the dock, having the engine and boiler houses placed at a low level to accommodate them. The pumps, with 18-inch suction pipes and 24-inch discharge pipes, discharge 10,000 tons of water per hour when working at their full capacity, and empty the dock in $2\frac{1}{2}$ hours. A small auxiliary pump removes the last of the water from the pump wells and culverts, and any leakage or drainage water.

The channel-way leading to the dock was excavated to a depth of 22 feet below high water of spring tides, with a width of 125 feet and side slopes of 2 to 1, through a stratum similar to that in which the dock was excavated, known as "till," a compact species of boulder clay exceedingly difficult to excavate.

James Watt Dock, Western Tidal Harbour, and Great Harbour, 1878–1886.

General Dimensions of Works.—The dimensions of these works are as follows:—

James Watt Dock.

	Feet.
Length	2,000
Breadth	300 to 350
Width of entrances	75
Depth of water on sill at high water of spring tides	32
" " " low " "	22
Length of jetty	800

Western Tidal Harbour.

	Feet.
Width of entrance	150
Depth at high water of spring tides	35
Length of quays (when completed)	2,480

Great Harbour (when completed).

Length	3,230 feet.
Width	600 "
Area	45 acres.
Depth at high water of spring tides	38 feet.

Totals.

Total water space	90 acres.
Total quay area	100 "
Total length of quays, over	3 miles.

Cofferdams and Earth Dams.—To exclude the water from the western end of the works, a cofferdam was constructed along the south-western side of the channel-way leading to the graving dock. One end of this dam abutted against the wing-wall of the graving-dock entrance, and the other end against the new south-west pier-head constructed at the outset. The central portion of the dam was a single pile structure backed with clayey material from the excavations. The end portions, next the masonry walls, had a double row of piles, 5 feet apart, with puddle clay between, and a backing also of selected clayey material behind the dam. The head of water against the dam, at high water of spring tides, varied from 10 to 36 feet. Through the double portion of the dam next the pier-head, four 24-inch cast-iron pipes, with sluice valves, were placed, for admitting the water to the dock works when completed, or if found necessary at any time during construction. Though the top of the dam was 7 feet above high water of spring tides, on the 26th January, 1884, when a spring

tide and severe storm occurred together, the tops of the waves passed over the dam, and the works were inundated for about 1 foot in depth.

To shut out the water from the eastern entrance works, an earth dam was formed with selected spoil from the excavations, having a head of water against it of about 20 feet at high water of spring tides. Its top was carried up to the general level of the quays, about 7 feet above high water.

Excavation, Dredging, and Embankments.—The excavation was about 1,200,000 cubic yards, of which about one-third was irregularly stratified and dislocated red sandstone rock, and two-thirds boulder clay or "till," similar to that met with in the graving dock, and equally difficult to excavate; but steam navvies were employed for the bulk of the work; and excavation by hand was restricted to confined places or very shallow depths, where the steam navvies either could not work at all, or not economically. The "till" overlaid the rock somewhat irregularly, and varied in thickness from a few inches at the east end of the dock, to over 50 feet in the north-west part. Bands of a clayey material, varying from two or three inches to several feet in thickness, were interstratified with the rock. In a few places where a fair face of solid rock was found, wedging was resorted to in order to obtain ashlar facing for the works; but generally the rock was excavated by blasting, and ashlar got from the most suitable portions, the remainder being deposited in the embankments. The excavated materials were deposited in the railway embankments connected with the dock, on the bed of the river and low-lying lands to the east and north of the new dock, to form a river embankment on the north side of the great harbour, and about a seventh part in Loch Long 7 miles from the works.

The toe of the slope of the embankment on the south side of the great harbour was founded at a depth of 20 feet below high water of spring tides, a trench for its reception being dredged out. Stone from the excavations was then tipped into the trench, forming a bank up to low water; and above this level, sandstone pitching, backed with stone refuse from the excavations, was continued up the $1\frac{1}{2}$ to 1 slope to quay-level, where the slope was finished off with rough sandstone coping set in cement concrete and mortar. The Lady burn was carried through this embankment in a pitch-pine trunk $12\frac{1}{2}$ feet high, 8 feet wide, and about 270 feet long, formed of an outer and inner skin of 4-inch planking with a framework between, filled in with fine Portland cement concrete.

The river embankment on the north side of the great harbour is pitched on its harbour side similarly to the slope on the south side, and founded in a dredged trench at the same depth below low water. The slope next the River Clyde, being open to the estuary with about 7 miles fetch, is subjected during the winter months to considerable wash in rough weather. The stone embankment and facing of this slope has therefore been formed of the largest sized stones from the excavations; and the pitching from low water up to coping, and the coping, 4 feet by 3 feet by 1½ foot, are set in a backing of Portland cement concrete, and grouted up with cement compo.

The bed of the estuary over the greater length of this embankment is very soft silt, into which the embankment sank down repeatedly, from 5 to 15 feet, in lengths of 100 to 500 feet, with very little warning, especially during very low tides when the weight of the embankment on the soft foundation, being out of water, was increased. Borings made at a part of the embankment where repeated subsidences took place, showed that the mud extended down over 110 feet below high water, and that the embankment at that place had sunk into the mud to the depth of 50 feet, at which depth the mud afforded sufficient support for the embankment as no further subsidence has taken place.

Walls.—The walls of the dock, and of the portion of the western tidal harbour constructed inside the cofferdam, are of the same type, varied only according to the soundness of the rock and the depth below quay-level at which it was found. The face of the walls has a uniform batter of 1 in 24 from coping level to within 6 feet of the dock or harbour bottom, from which point there is a curved toe to a radius of 6 feet, Fig. 3, Plate 7. Borings along the lines of the quay walls, and the centre line of the dock and tidal harbour, at intervals of 100 feet, carried down several feet below the finished bottom of the work, showed that rock existed at moderate depths over the larger portion of the site of the works. The rock, however, turned out to be so much intersected by joints, dislocations, and bands of clay, that, for the most part, a wall had to be built from the bottom of the dock; and only in a few places could the wall be commenced at a higher level, or occasionally merely facing the upper part of the rock suffice. A section of this wall, where the dock-bottom was of till, is shown in Fig. 3, Plate 7. Where firm rock was found some feet below coping level, the corresponding portion of wall was built upon it, and the sound rock dressed off and utilized for the wall below; and when the rock rose to coping level and extended down to dock-bottom, it

was merely faced with ashlar down to 10 inches below low water of spring tides.

The western tidal harbour is 3 feet deeper than the dock, and the portion of its quay walls constructed within the cofferdam are somewhat heavier than those of the dock. The body of the wall is rubble concrete, composed of 3 parts of ballast, 3 of coarse sand, 1 of Portland cement, and 6 of large stones. As the excavation produced an abundance of large stones, the wall consists practically of large stones with a 3 to 1 mortar, and ballast or small stones forced into the mortar. The face of the wall, from foundation level to the underside of the granite ashlar, 10 inches below low-water level, is of brickwork, 2¼ feet thick, with three horizontal ledges, each 2 feet thick by 3 feet wide and subdivided vertically by counterforts, 3 feet by 3 feet, placed 11½ feet apart centre to centre, and extending for the full height of the brickwork, thus bonding the brickwork thoroughly both vertically and horizontally to the rubble concrete. The brickwork is set in 3½ to 1 Portland-cement mortar, and pointed with neat cement. During the progress of the works, sandstone ashlar from the excavations was substituted for the brickwork facing at the request of the contractor, above the top of the curved toe; and a large portion of the walls has been so constructed. The sandstone and granite ashlar and coping were set in mortar composed of 3 parts of clean sharp sand to 1 of Portland cement, and pointed with 1 to 1 Portland-cement composition.

From foundation level to low water, the walls are backed with quarry refuse and sand from the rock excavations, washed in with Portland cement in the proportion of 1 part of the latter to 15 parts of the former. From low-water level to 1 foot below coping, the filling between the back of the walls and the slope of the excavations was of "till" well rammed in layers. Temporary drains piercing the walls at intervals drained away any water from the back of the walls.

The portion of the western tidal harbour wall outside the cofferdam was built differently, Fig. 4, Plate 7. A trench was first dredged for this wall down to 39 feet below high water. Greenheart gauge piles were then driven 7 feet apart along the line of the wall, 6 feet below the bottom of the trench; and between these, greenheart 7-inch sheeting piles were driven 3 feet below the bottom of the dredged trench, whole balks being used round the corners of the pier-head. These piles, which formed a facing to the concrete of the under-water portion of the wall, were cut off at 2 feet above low water, where they are bound together

on the inside by 14-inch greenheart walings. The piling is backed by concrete, 3 feet in thickness, composed of 7 of sand and ballast to 2 of Portland cement; and behind this, the body of the wall is of concrete composed of 6 of sand and ballast to 1 of cement. The concrete was deposited under water in a plastic state;[1] and the front and back concretes were brought up simultaneously. To prevent separation between the greenheart piling and the concrete, 1¼-inch tail-bolts, extending to the back of the fine concrete and having tails turned up and down for 9 inches each way, were placed through the piles. The ends of these tail-bolts were thus anchored in the concrete, and kept the piling close up to the face of the work. There is always a difficulty in getting a sound facing in this class of work, and much unreliable and expensive work is done under water with concrete deposited *in situ*. The greenheart piling provides a sound facing which, if not indestructible, lasts for a long period; but if the Author had to construct this pier-head over again, he would adopt the system which he has used so largely and successfully in Jersey, Yarmouth, and Poole, of constructing the wall from foundation to cope of concrete blocks, faced with granite ashlar, and grouted with neat Portland cement into a monolithic mass.

The south-west pier wall above the greenheart piling is constructed in the same manner as the dock walls, except that, immediately on top of the piling, a course of granite headers is laid tailing into the body of the work for 4 feet from the face of the wall, so that, should any accident befall the greenheart piling, the ashlar facing would not be affected thereby; compare Figs. 3 and 4. The greater portion of the south-west pier-head is founded on soft strata; and the return wing next the adjoining shipbuilding yard rests on bearing piles, as the firm strata near the channel-way of the Clyde dip very suddenly to a great depth.

Entrance Works.—There are two entrances to the James Watt dock, the western from the western tidal harbour, and the eastern from the great harbour. Both entrances are alike as regards width of opening, depth of water on sill, general arrangements, and details as far as possible, which simplified construction, Fig. 5, Plate 7. Moreover, the caissons being alike, can be transferred to either entrance, and used as dams in the case of repairs being necessary to the inverts of the entrances or caisson berths. The Author constructed these entrances with level sills, in order to suit the midship section of the modern largest-sized

[1] Minutes of Proceedings Inst. C.E., vol. lxxxvii. p. 65.

merchant vessels, many of which have an exceedingly small rise of floor, sharp turn at bilges, and sometimes bilge keels.

The sills, and the inverts of the caisson berth and chambers, and the facing of all the walls up to 10 inches below low-water level, are of brickwork, with ledges, counterforts, and cross walls. Above that level, there is granite ashlar and coping similar to the dock walls. Granite quoins with polished projecting meeting-faces, 12 inches wide by $\frac{3}{4}$ inch projection, are built into the inverts, or level sills, and side walls.

Outside the outer and inner inverts, berths have been provided for the caissons, and quoins with meeting faces built into the work, whereby if repairs should have to be done to either entrance, the caisson belonging to that entrance could be placed against the outer face of one of the inverts, and the caisson from the other entrance against the outer face of the other invert, and the water then pumped out and the repairs executed, the dock during such repairs being used as a tidal harbour. For repairs to the caissons, or cleaning and painting them, the caisson chambers can be utilized as dry docks. Sufficient space has been left between the caisson and the side walls of the chamber for men to work conveniently; and in order to shut the water out from the chamber, timber dams or gates can be placed in grooves, 2 feet wide, formed for that purpose in the side walls and bottom of each chamber near to the entrance. To scour out any silt which may settle in the chambers or berths, sluice-openings are provided in the end walls. The chambers are covered over so that their surfaces are uniform with quay-level. The covering, of sufficient strength for railway traffic, consists of wrought-iron girders, carrying brick arches and granite setts on the top, Fig. 5, Plate 7.

Under the western entrance, a subway gives access to the north side of the dock when the dock entrance is open, and also carries the water, gas, and hydraulic mains, and telegraph wires across. This subway is 8 feet high by 6 feet wide, benched out to 8 feet wide at 3 feet above floor-level, and is lined with white enamelled bricks, Fig. 5, Plate 7. The floor of the subway is 59 feet below coping, and is reached by granite steps. A small hydraulic pump, in a recess in the side wall of the subway, carries off any water coming in either from the surface or by soakage through the brick-work.

On the northern side of the western entrance there are four levelling culverts, each 6 feet high and 4 feet wide, having the soffits of their arches at low-water level.

Water from springs and from runs along the joints in the rock,

was collected and allowed to rise in earthenware pipes to the elevation due to its head; and when the new work had been brought up above the level of the water, and had firmly set, the springs were plugged by neat cement grout put down the pipes.

Caissons and Travelling Bridge.—The Garvel graving dock, and the eastern and western entrances of the James Watt dock are each closed by a caisson, Fig. 6, Plate 7. A travelling bridge at the entrance to the old west harbour, similar in design to the caissons, allows the tide to pass freely into and out of the harbour, Fig. 7. These caissons and travelling bridge are constructed on the type invented by the Author. The rolling caissons, worked by machinery, give great facility in opening and closing the entrance quickly, even with a considerable current running through it, an essential point for the travelling bridge at the old west harbour, which has to be opened about a dozen times a day. A bridge, moreover, is provided across the harbour or dock entrance on the caisson, sufficient for the heaviest traffic; whilst no quay space is occupied by it, for by supporting the platform of the bridge on levers with counterbalance weights, on the bridge being opened the platform automatically falls, and passes under the covering platform of the caisson chamber.[1] The caisson is housed out of danger in a recess; and a large saving in cost is effected by the reduction in the masonry, as compared with an entrance with a pair of gates. Repairs also are facilitated by this arrangement, which admits of the caisson being taken out of its berth and placed against the outer face of the invert. As the ends of the Garvel graving dock caisson are square to the sides, it was necessary for the dock entrance to have heavily battered side walls to afford sufficient clearance for the ends in removing or replacing the caisson. The caissons for the two entrances to the James Watt dock have bevelled ends, which admit of the side walls of the entrances being vertical. The extent of the bevelling is regulated by the condition that a diagonal on plan of the caisson should not be greater than the length of the longer face of the caisson. In removing the caisson from its berth, it is first floated up sufficiently to clear the sill; it is next hauled back about a foot into the chamber, to allow the meeting face at the opposite end to clear the side wall of the entrance; and it is then swung round out of its berth. With bevel-ended caissons, the inner and outer inverts of the dock entrance are of different spans, being 75 feet and 80 feet respectively at the James Watt dock.

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[1] Minutes of Proceedings Inst. C.E., vol. cxi. p. 53, and Plate 3, Figs. 3 and 4.

At the graving dock, the rollers are fixed to the caisson itself, and the rails fixed to the masonry; whilst at the James Watt dock, the rails or keels are fixed to the caissons, and the rollers are mounted in boxes deeply bedded in the masonry. The latter arrangement is generally preferable, as the rollers can in this case be easily removed and replaced again by a diver. Moreover, in removing the caisson from its berth, it does not require to be floated so high to clear the sill when it has no rollers attached to its bottom.

The raising and lowering of the deck is rendered automatic by the nosing rollers attached to the longitudinal girders at the one end of the deck, and the shoes on the same girders at the other end, Fig. 7, Plate 7. When the caisson closes the entrance, the deck is held firmly in position between the raising boxes and nosing girder, and does not vibrate at all under the heaviest traffic. The plummer blocks carrying the rocking shafts, with the counter-balanced levers and lowering deck, are 9¾ feet apart, and are supported on plated columns carried direct to the bottom of the caisson, and connected longitudinally to each other and to the ends of the caisson, and transversely to the sides of the caisson, by angle-irons.

The water-tight deck is 12 inches above low water. At a lower level there are two openings on each side of the caisson, 9 inches square, connected together and to the water-tight deck by piping, which allows the tide to pass freely into and out of the compartment above the water-tight deck. The water-level is usually higher in the dock than outside when the entrance is closed, but the opposite might be the case at high water, if the entrance was not opened for one or more tides; and to provide for such a contingency, and make certain that the level of the water above the water-tight deck would be always equal to the highest water-level, whether inside or outside the dock, a self-acting pendulum valve is connected to the pipes under the water-tight deck. This valve swings freely to the side opposite to the greatest pressure, and admits the water from the side with the greatest pressure into the compartment above the water-tight deck, whilst closing the pipe opening on the other side, and so prevents the passage of the water straight through the caisson.

The caisson is hauled into and out of the chamber by two endless pitch 1½-inch chains attached to a yoke at the end of the caisson, and passing round pitch-wheels on a driving shaft at the inner end of the chamber, and round grooved return wheels at the outer end. At intervals along the sides of the chamber, the chains are supported by rollers which are carried upon brackets

secured to the side walls. Provision is made for taking up the slack caused by the lengthening of new chains, after they have been in use for some time, by long links having a series of pin-holes. The power required for hauling the caisson in ordinary working condition is small, as the weight on the bottom rollers is only about 40 tons. The Author, however, provided for the contingency of the water-tight compartment being filled with water, when the weight to be hauled would be about 700 tons.

The double-flanged cast-iron rollers over which the caissons travel, are 18 inches in diameter, and are spaced 9 feet apart. The keels of the caisson are solid steel bars, 8 inches wide by 4 inches thick, scarfed at their junctions and riveted to the bottom of the caisson with countersunk rivets. The outer sides of each of these keels are swelled at four points, 1½ inch beyond the fair lines of the keels. The swelled parts of the keels when the caisson is in position closing the entrance, are just clear of the rollers, and force the timber meeting faces of the caisson off the polished granite meeting faces of the masonry, and keep them apart while the caisson is being hauled in and out. The breadth of the caisson over the timber meeting faces is 19 feet 10 inches, and the width between the granite faces 20 feet, giving a clearance of 2 inches. The meeting faces of the caisson are of greenheart, 14 inches by 8 inches, secured to the plating by angle-irons. The granite and greenheart meeting faces were dressed to true planes by aid of plumb rules, fine steel wires stretched across their faces, and offset blocks, so that when the caissons were floated into their berths, the timber and granite meeting faces coincided perfectly, and no leakage took place. A difference of head of 3 to 4 inches, on one side or the other of the caisson, is sufficient to shift it from one face to the other.

The travelling bridge at the entrance to the west harbour consists of three piers forming water-tight tanks, each 18 feet by 18 feet, connected together by girders at top and bottom, with spaces between, 23 feet in width, Fig. 7, Plate 7. Under each pier, six rollers are attached to the bottoms of these girders. The bridge has a lowering deck constructed similarly to the decks of the caissons, and laid with rails for railway traffic.

A three-cylinder hydraulic engine, driving gearing having quick, intermediate, and slow motion, works each of the caissons and the travelling bridge. The quick motion used ordinarily, travels the caisson backwards or forwards in about two minutes. The slow motion enables the caisson to be traversed when, owing to the water-tight compartments being filled with water, the entire

weight of the caisson and ballast rests upon the rollers. The load to be hauled on the slow speed was taken as equivalent to a dead lift of 75 tons, and on the quick speed of about 19 tons, each acting at a leverage of $10\frac{1}{8}$ inches from the centre of the hauling shaft.

Warehouses.—On the south side of the James Watt dock, at the east end, a block of warehouses of 676 feet in length has been erected, one warehouse being 275 feet and one 223 feet long, 106 feet wide, and 47 feet high, and two warehouses 89 feet long, 106 feet wide, and 57 feet high to eaves, and 97 feet to ridges of roofs. The fronts of the warehouses are constructed of cast-iron columns and girders, with wrought-iron sliding doors; and the back, end, and division walls are of brickwork. The two longer warehouses are arranged for two floors above quay-level; but at present they possess the ground floor only, and a portion, 13 feet wide, of the upper floor, forming part of the roof of the covered way in front of the warehouses. The two shorter warehouses have four floors above the quay-level; and the insertion of an intermediate floor, between the ground and first floors, has been provided for. The first floor is made fire-proof, with 10 inches by 6 inches rolled beams, spaced $4\frac{1}{6}$ feet apart, carrying brick arches $4\frac{1}{2}$ inches deep at the crown, on top of which the floor is rendered with 1 to 1 Portland cement granolithic composition 1 inch thick. The upper floors and roofs are of timber. A well-hole in the centre of each of these warehouses, 24 feet long by 16 feet wide, enable cranes placed on the top floors to load or unload goods from any floor into or out of railway wagons on the ground floor. The warehouses are intended for general merchandise; but the columns carrying the floors have been cast with openings fitted with valve-flaps, in order that they may be utilized as ducts for distributing grain over any portion of any floor, and also for transferring it from a higher to a lower floor, or for loading railway wagons inside the warehouses. In each floor there are openings with branch pipes connected to the vertical columns, for receiving the spouts of portable hoppers when it is desired to transfer grain to a lower level; but cover-plates ordinarily close the openings in the floors.

There are doorways on the ground floor through the brick party walls separating the warehouses, for railway wagons to pass, closed by double iron doors separated by an air space of $9\frac{3}{4}$ feet. In front of the warehouses there is a covered way, $27\frac{1}{2}$ feet wide, half outside and half inside the warehouses, enabling loading and unloading to be carried on under cover. This corridor, outside the line of warehouses, is covered with a fireproof

floor similar to that of the warehouses, and at the same level, forming a continuous platform, 13 feet wide, in front of the warehouses, on which goods are landed and conveyed into any of the warehouses, thereby enabling imports to be dealt with on the ground floor, and exports on the upper floors, and thus admitting of the loading or unloading of vessels to be largely done by gravitation.

Railway Connections.—The Caledonian and the Glasgow and South-Western Railways are both connected with the railways round the docks. The Caledonian main line to Greenock passes near the docks at a convenient elevation for access thereto, so that only a short branch line and a bridge spanning the Port Glasgow Road had to be made by that company, Fig. 1, Plate 7. The Glasgow and South-Western line is about half a mile from the docks, and at a high elevation, rendering necessary about 1½ mile of new line, with some heavy cuttings and embankments, a considerable length of tunnel, and a high viaduct. The railway system laid round the dock consists of three double lines on the south side of the dock, namely, one at the back, one through the centre, and one in front of the warehouses, and various other lines along the quays, as shown in Fig. 1, Plate 7. At the east end of the dock, the lines converge into a double line and join the Glasgow and South-Western Railway on the quay-level. The connection with the Caledonian Railway is formed about 20 feet above quay-level, necessitating a short length of inclined way, partly on embankment and partly on a brick viaduct. The rails along the south and north sides of the dock, and on the jetty, are laid with guard rails and causewayed between. To prevent the quay from being broken up by switch-boxes and levers, a special compact form, designed by the Author, was used, with a removable lever, the lever being fitted into a socket at quay-level, and the box and the connecting rods being all under the surface of the quay.

Hydraulic System.—There are two sets of hydraulic pumping plant, one at the Garvel Park works, and one at the Victoria harbour, for supplying the cranes at the old harbours. Both sets of plant are connected, affording steadiness of supply, and enabling one set of pumping plant to be stopped for a short period and overhauled with little inconvenience to the working of the cranes. When, however, the cranes are fully employed, the full pumping-power is required, and scarcely suffices for the work. The plant at the Victoria harbour consists of a pair of horizontal compound condensing engines, with cylinders 16 inches and 2 inches in

diameter and 20 inches stroke. The pressure-pumps are $4\frac{3}{4}$ inches in diameter, and the accumulator is 17 inches in diameter and 17 feet stroke. The boilers are $23\frac{1}{4}$ feet long and 6 feet in diameter, with a working pressure of 50 lbs. The hydraulic plant at the James Watt dock is similar to that at the Victoria harbour.

The pressure in the pipes is 750 lbs. per square inch. The internal diameter of the main pressure-pipes is 5 inches, and of the main return water-pipes 7 inches. Along the south side of the James Watt dock, and from the Port Glasgow road to the north side of the dock, the pipes are laid in subways. The remainder of the pipes, at the new and old works, are laid in the ground.

Cranes.—The cranes provided for these works at the outset were two 20-ton steam travelling cranes on the coaling jetty, mounted on gantries; two 3-ton hydraulic travelling cranes, likewise mounted on gantries, and six 3-ton fixed hydraulic warehouse cranes; but other cranes have since been added. The gantries carrying the 20-ton cranes are $17\frac{1}{2}$ feet high, and span a double line of railway. The height from high-water level to the centre pin of the pulley at the jib head is 70 feet, which was provided for putting masts in the large four-masted sailing vessels constructed in the ship-building yards adjoining the docks.

Twenty-six wagon-loads, containing 7 tons of coal on the average, can be put on board by each of these cranes in an hour; but this rate of coaling cannot be maintained, as the trimmers cannot keep pace with it, especially where the hatchways are confined, as in vessels constructed for general cargo, which is the case with the majority of vessels shipping coal at these docks.

The 3-ton travelling hydraulic cranes are placed in front of the warehouses on the south side of the dock, and load or unload to or from vessels on to the quays or into the warehouse doorways; and the tops of the gantries carrying cranes are level with the platform in front of the warehouses.

In order to keep the warehouses as near the dock side as possible, consistently with having a double line of railway in front, the Author saved the space which would be occupied by the back legs of the gantry by making the back wheels run in a channel-way along the front edge of the platform, which also reduced somewhat the cost of the gantries. The cranes mounted on these gantries have a lift of 96 feet, which enables them to lift goods from the bottom of a deeply-laden vessel, and place them in the doorways of the top storey of the highest warehouses.

Surfaces of Quays, and General Fittings of Dock.—Certain portions

of the quay have been laid with 4-inch granite cubes set on an 8-inch bed of 8 to 1 Portland-cement concrete, and grouted with 2 to 1 Portland-cement composition; and other portions are bottomed and metalled. The surfaces of the quays slope inwards from the coping with an inclination of 1 in 100; and the tops of the rails and guard-rails round the quays are laid flush with the adjacent pitching. Moreover, the flange space between each rail and guard-rail is filled up with cement composition to within 2 inches from the top of the rails, these shallow narrow grooves forming the only depressions in which water can lie during wet weather.

Bollards of two types, placed alternately at intervals of 46 feet, are fixed along the coping of the quay walls, thus avoiding interruption of railway traffic by mooring hawsers. The bollards coincide in position with the centres of the counterforts of the dock walls, into which they are firmly anchored. The projecting wrought-iron bar through the head of the one type of bollard, and the projecting hooked nose at the back of the others, prevent the mooring cables from slipping off when the vessels are high out of the water.

For handling the railway traffic inside the warehouses and along their front, and also the coal traffic on the jetty, hydraulic capstans have been placed in the 6-foot way at convenient intervals.

At the south-west pier-head, rolling fenders, 5½ feet in height and 3 feet in diameter, sheathed with wood and having vertical spindles, are placed in recesses in the walls. The levelling culverts at the western entrance, and the sluicing culverts at both entrances, for scouring the caisson berths and chambers, are fitted with greenheart paddles, 11 inches thick, worked by direct-acting hydraulic rams, in granite cloughs in the culverts with 1 inch clearance.

Vertical ladders of greenheart have been fitted in recesses in the quay walls, at intervals of 184 feet, extending 16 feet below coping; and six flights of granite steps have been provided in the James Watt dock, and two flights in the western tidal harbour, down to about low-water level.

River Lines.—With the object of obtaining a cheaper site for the deposit of the excavations from the Garvel Park works than Loch Long, and also to utilize the material, the Author, in 1868, designed a scheme of harbours comprising the reclamation, partly as harbour area and partly as quayage, of the whole of the foreshore, water area, and sand-banks lying in the embayment on the south side of the navigable channel-way between Garvel Point and Inch Green, a frontage of about 2,000 yards, with an extreme width of 550 yards.

An improved channel for the Clyde, following generally the existing line of quays along the frontages belonging to the Greenock Harbour Trustees, that of the properties of the foreshore owners, and of low-water mark, formed also an essential point of this scheme, Fig. 1, Plate 7.

The foreshore properties lying between the Garvel Park and Inch Green estates of the Trustees, were gradually acquired for about half the length of the frontage to enable the proposed scheme to be carried out. Depositing area sufficient for the whole of the excavations was thus obtained; but parliamentary powers to deposit over the site of the river embankment, forming the north quay of the great harbour, were not obtained until 1880–82. The works had then been in progress for two years; and the other places of deposit on the foreshore of the newly-acquired properties having been filled up, 174,040 cubic yards of spoil were deposited in Loch Long by hopper barges, before the river embankment could be commenced. Depositing in Loch Long cost 1*s.* 4*d.* per cubic yard; in the river embankment it cost only 3*d.* per cubic yard. The saving by depositing the remainder of the excavations in the embankment was £50,000; whilst a large harbour and extensive quays were obtained gratis.

As the question of river lines concerned the Clyde Navigation Trustees as well as the harbour trustees, a new body was created in 1870, designated "The Clyde Lighthouses Trustees," composed of members of the aforesaid bodies, to carry out the improvement of the navigable channel-way, which has been effected on lines, depths, and widths closely resembling those laid down by the Author in 1868, Fig. 1, Plate 7. A central depth of 23 feet for a width of 200 feet, sloping up to 18 feet along the frontage of the Greenock quays, was adopted in 1880; and in 1890 it was agreed to widen the 23-foot depth to 300 feet.

Dredging Plant.—The Greenock Harbour Trustees undertook to execute a portion of the dredging required for the improvement of the navigable channel; and a large amount of dredging had to be done in deepening the western and great tidal harbours to their full depths. To carry out this work, including dredging boulder clay, which the old stationary bucket-ladder dredger at the port was unable to cope with, a 1,000-ton hopper-dredger was in 1876 constructed for the work by Messrs. Simons under the advice of the Author. This dredger, "Greenock," is 182 feet long between perpendiculars, its breadth of beam is 38 feet, moulded depth 13½ feet, draught when light 6½ feet, and loaded 12⅓ feet, rate of dredging in sand, gravel, soft clay, or free soil, 300 tons per hour, maximum

depth of dredging 32 feet; and it is fitted with side shoots for loading hopper barges. The speed of the "Greenock" when fully loaded is 8 miles an hour. The bucket-ladder well is in the forward part of the vessel; but an improvement subsequently introduced by the Author was the construction of hopper dredgers with stern wells.

Some stiff boulder clay had to be dredged in the improvement of the channel-way and deepening the western tidal harbour, for which blasting was freely resorted to, especially where the boulders were large or numerous. A chain of strong buckets, alternated with picks, was used; but renewals and repairs were heavy, and delays in replacing buckets frequent. As the breakages occurred chiefly at the riveted junctions, the Author, in 1880, designed a bucket without riveted connections, and with interchangeable parts, so that renewals could be quickly made by the men on board from spare parts. It consists of a back, body and lip. The back is of cast steel, and forms a combined set of bucket links, a bucket bottom, and bucket back; and the steel bucket body is placed on the top of the bucket back, and forms, with the bucket back, a complete bucket. The bucket lips, varied in form according to the nature of the material, are fitted on to the central portion of the bucket body; and the hook bolts at the other end of the body keep them steady in position. This bucket has been used on the "Greenock" for the past fifteen years, and has proved very satisfactory as regards durability and facility of renewals.

Steam-Boat Quay, and West Quay.

New wharves were constructed along the river frontage between the entrances to the east and west harbours, and from the west harbour entrance to Caird's shipbuilding yard, known as the steam-boat quay and the west quay respectively, in order to obtain a greater depth of water than existed at the old quays, Fig. 1, Plate 7. These wharves were erected in front of the old irregular quays, parallel to, and 25 feet back from the improved channel-way, adding about 5,380 superficial yards to those quays which are much used by the coasting traffic; and a depth of 28 feet at high water has been provided in front of them. Borings taken along the line of the new work showed that a firm stratum, fit for quay-wall foundations, was only reached at great depths, attaining 70 feet below high water in one or two places, and therefore timber-work was adopted. A trench was first dredged along the front line of the new work, and after driving the piles, a bank of whinstone rubble

was deposited to serve as a toe to the filling between the new and old work. To increase the resistance of the main piles to outward thrust, wrought-iron shields, 5 feet by 3½ feet, were bolted to the faces of the front piles before driving, and then driven down so that their tops are 2½ feet below the level of the finished dredged bottom. Sheeting piles and horizontal planking were placed along the line of the front piles to retain the bank of rubble stone; and for the retention of the filling behind the back line of main piles, a double row of sheeting piles was driven, the lower ends of which extended about 4 feet into the rubble bank; and between the sheeting piles, a wall of 8 to 1 concrete was brought up to the deck planking. The greenheart front and back piles, 14 inches to 16 inches square, 8 feet apart, and driven into the hard clay, are joined by half-timber ties; and whole-timber struts were inserted between the piles, and the ties and struts bolted together. The quay was planked with 3-inch Gardnerized fir planking, and whinstone pitching laid thereon, on a bed of Portland-cement mortar; and the face of the quay is protected by segmental rubbing irons.

The travelling bridge, spanning the west harbour entrance 103½ feet wide, connects the steamboat and west quays. Such a bridge is the most suitable for this site, as a swing-bridge would have been exceedingly costly, owing to firm strata being only reached about 60 feet below high water, and would have projected out inconveniently when open, owing to the narrowness of the quay. The bridge cost only £9,700, including hauling machinery; it does not occupy any quay space, and with due care in painting, should have a long life. A timber gridiron, resting upon piles driven into the hard clay, and encased in plastic concrete, carries the rails for the bridge, fastened on greenheart longitudinals. The rails, 9 inches by 4 inches solid section, are laid to a gauge of 16 feet; and their tops are 26 feet below high water.

These new quays, together with the necessary extensions of sheds on both quays, and rearrangements of lines of rails, cost about £70,000.

The resident engineers for the graving dock were first Mr Thomas Shaw, and afterwards Mr. C. W. Methven, M. Inst. C.E., Mr. D. Macalister, M. Inst. C.E., was resident engineer on the James Watt dock, western tidal, and great harbour works. For the steamboat and west quays, and the maintenance of the old harbour works, Mr. Methven was the resident engineer, and was succeeded by Mr. Robert Crawford, M. Inst. C.E., the present engineer to the Greenock Harbour Trustees. The Author was

engineer-in-chief for the whole of the works, and Mr. William Jaffrey, M. Inst. C.E., acted as principal assistant for the James Watt dock works.

The Paper is illustrated by twenty-four drawings and tracings, from some of which Plate 7 has been compiled.

APPENDIX.

Schedule Rates for Work executed.

Excavation of boulder clay, including depositing within 40 yards of the coping	1*s*. per cubic yard.
Rock excavations, including deposit	1*s*. 6*d*. " "
Brickwork set in 3½ to 1 Portland-cement composition	24*s*. " "
Rubble concrete, composed of 3 parts sand, 3 parts ballast, 1 part Portland cement, and 6 parts large stones	10*s*. " "
Granite ashlar in dock walls, set in 3 to 1 Portland-cement mortar and tipped with 1 to 1 Portland-cement composition for 4 inches in from the face	3*s*. per cubic foot.
Granite coping of walls	4*s*. " "
Greenheart piling of face of south-west pier-head	6*s*. " "
Pitching at James Watt dock, of 4-inch granite cubes laid on a bed of 6 to 1 concrete and grouted with 3 to 1 Portland-cement composition	13*s*. per sup. yard.

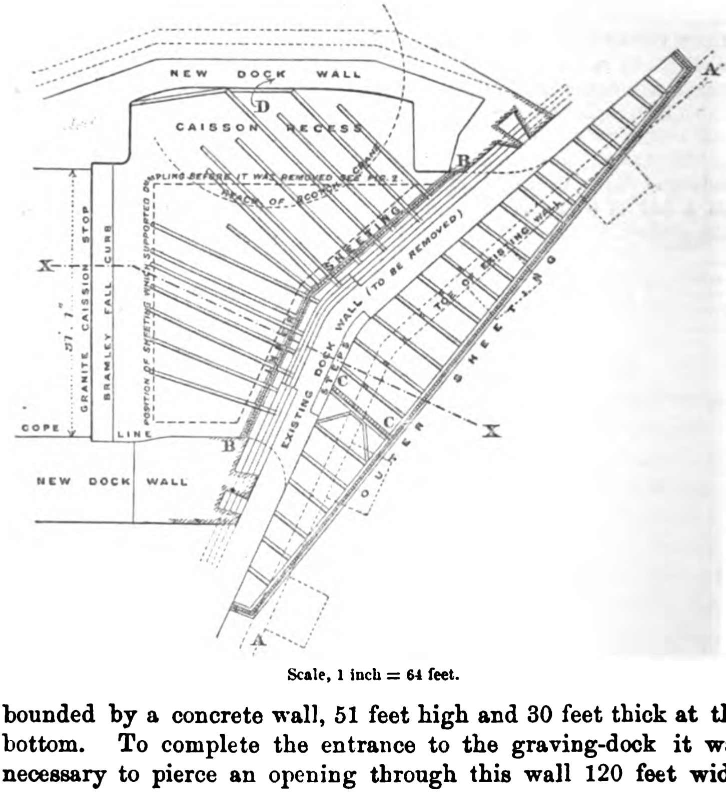
(Paper No. 3019.)

"The Removal of a Dock-Wall to form an Entrance to the Prince of Wales Graving-Dock, Southampton."

By Francis Ernest Wentworth-Sheilds, Assoc. M. Inst. C.E.

The Prince of Wales Graving-Dock at Southampton is approached from a deep tidal basin known as the Empress Dock, which is

Fig. 1.



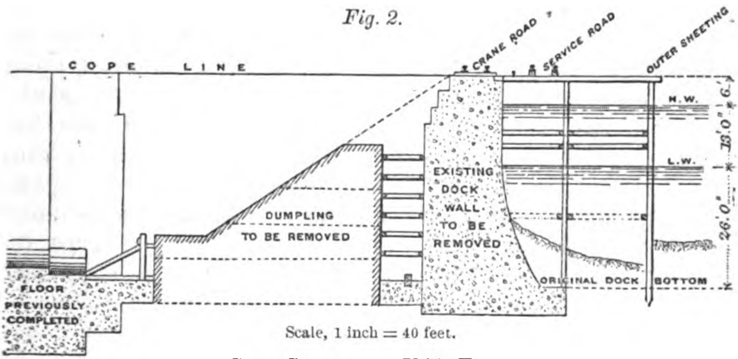
Scale, 1 inch = 64 feet.

bounded by a concrete wall, 51 feet high and 30 feet thick at the bottom. To complete the entrance to the graving-dock it was necessary to pierce an opening through this wall 120 feet wide

and 43½ feet deep, to give a depth of 24 feet 6 inches below low water of spring tides.

The old wall which had to be cut away was enclosed by two rows of watertight timber sheeting, A A and B B, *Fig. 1*, the ends of which were firmly secured to the wall. Water was admitted on both sides of this enclosure, but was pumped from within it; so that under the protection of the sheeting the concrete could be blasted and removed by hand. The work of piercing the entrance had been left until the last, as the old dock-wall had served to shut out the tidal-water during the construction of the graving-dock. The new walls had in January, 1895, been virtually completed as far as the entrance; also the new floor, except for a length of about 60 feet immediately behind the old wall. Over this portion the earth dumpling had been sloped off, *Fig. 2*, as it

Fig. 2.



Scale, 1 inch = 40 feet.

CROSS-SECTION ON X X, *Fig. 1.*

was considered that the wall would be unable itself to withstand the backward thrust of the water outside. Before the water could be admitted to the graving-dock side of the enclosure it was necessary to complete the floor. The earth dumpling had accordingly to be removed, and arrangements to be made to prevent any backward movement of the old wall.

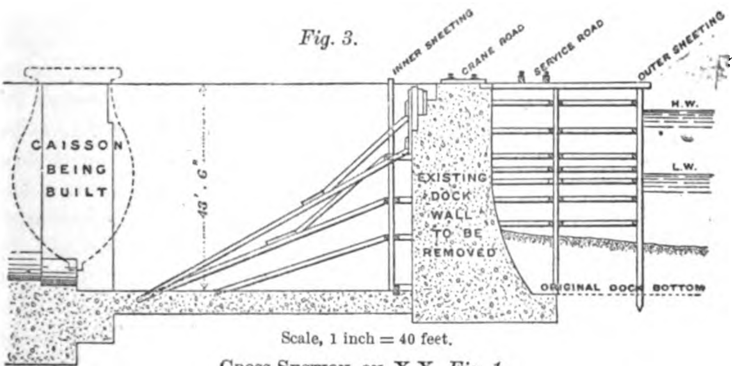
The outer sheeting, A A, *Fig. 1*, consisted of a single row of timber piles. To avoid interrupting traffic in the Empress Dock this sheeting had to be kept close to the wall. Consequently many of the piles, instead of being driven into firm ground, merely passed through the overlying mud, and rested on the toe of the wall, or on large concrete blocks built in front of that toe. The piles were of sawn pitch-pine, 13 inches square, generally in one piece, 40 feet to 50 feet long. They were driven by a steam pile-engine

with a 20-cwt. monkey. They were not tongued, but were shod with raking shoes, and fitted tightly. Sluices were cut in the sheeting to allow the enclosure to be flooded at any time, and to let falling tides escape before pumping was commenced. The ends of the sheeting were closed into the dock-wall by piles cut to fit its curved batter and strongly secured to it by lewis-bolts. These return ends were strengthened with stout angle-straps bolted to several piles, and by chains passing round the corners and lewised into the wall. Several tons of old rails and iron blocks were stacked on the sheeting and walls to prevent their being floated up; and to prevent water from passing in under the pile shoes, clay and gravel were thrown out on both sides of the sheeting, forming a watertight pediment. The sheeting was then stiffened by strutting it to the wall face. The struts were of 12-inch square pitch-pine, 10 feet apart horizontally. In the centre of the sheeting, where the struts were of considerable length, they were supported on intermediate piles. Two frames were first inserted above low water, *Fig. 2*, the walings being bolted to every second or third pile. This greatly increased the stability of the sheeting, though it made the walings somewhat troublesome to remove subsequently. To continue the strutting downwards, the space between the wall and the outer sheeting had to be pumped out. A transverse dam, C C, *Fig. 1*, of whole-timber piles, was driven to divide the enclosure into two parts, and, by allowing each part to be pumped out separately, to save time and risk. To prevent the feet of the piles moving inwards, a frame of struts was fixed by divers at a depth of 11 feet below low water. Pumping was commenced early in May; the plant consisting of a 6-inch and a 3-inch pulsometer, worked from a 25-HP. boiler. The sheeting leaked considerably at first, but caulking with oakum and sealing with clay and gravel were resorted to with good effect. An 8-inch Woodford pump was added, and in a few weeks the water could be kept low enough to insert the next frame of struts. Care was taken not to lower the water too much at first, so that the sealing material might become consolidated by the gradually increased pressure. As the water was lowered, new frames of struts were inserted about 4 feet apart vertically until the divers' frame was reached.

Meanwhile the inner sheeting, B B, *Fig. 1*, was erected. A timbered trench was in March, 1895, sunk behind the old wall throughout the exposed length, *Fig. 2*. It was 8 feet wide and was taken down to 47 feet 6 inches below coping-level, that is, deep enough to allow a strip of the permanent floor to be built

within it. Although it was immediately behind the wall, the trench was fairly dry; the soakage water was thrown by a 3-inch pulsometer into a manhole communicating with the contractor's drainage-pumps. The bottom of the trench was reached about the end of April, and 5 feet 6 inches of concrete was spread over it, forming part of the permanent floor. The excavated material was removed and the concrete was lowered by two 3-ton travelling cranes which stood on the old dock wall. A service-road alongside held the tip-wagons and ballast-trucks. A whole-timber sill was next buried flush in the concrete floor within the trench, parallel to the old wall and 2 feet 6 inches from it. It was secured to the concrete by 1-inch vertical lewis-bolts, 2 feet 6 inches long and 10 feet apart. On this sill rested another, secured to the first by 18-inch coach-screws 5 feet apart; and the

Fig. 3.



Scale, 1 inch = 40 feet.

CROSS-SECTION ON X X, *Fig. 1.*

uprights forming the sheeting were secured to this upper sill by 1-inch bolts, a layer of tarred felt being interposed to make a watertight connection. The joints between the uprights were caulked with oakum. The sheeting was strutted to the back of the wall and had sluices cut in it similarly to the outer sheeting. The uprights were not erected until the whole of the earth slope, and consequently the trench struts, had been removed.

Immediately after the trench was sunk, and while the concrete was being laid, the work of removing the other portion of the earth dumpling was commenced. The material was filled into skips travelling on narrow-gauge trolleys, which were lifted by a Scotch crane fixed on the new dock wall at D, *Fig. 1.* In this way the excavation was completed in four 8-foot lifts, *Fig. 2,* during the month of May. The soakage water was led to a central

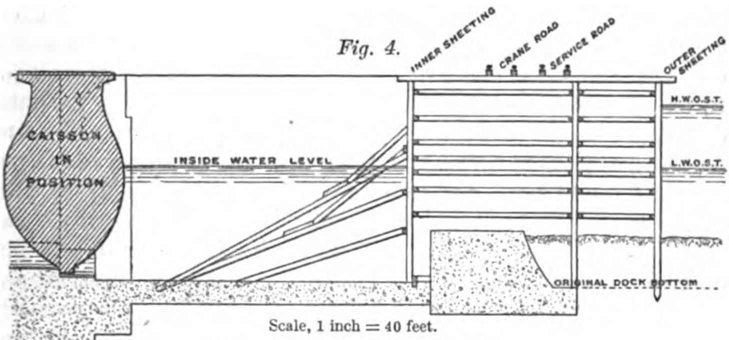
sump and was removed by the 3-inch pulsometer. As soon as any portion of the floor was excavated, vertical shutters were erected round it, and the concrete was inserted. While removing the earth dumpling, special arrangements had to be made to prevent the old wall from being forced backwards by the pressure of the outside water. For this purpose long raking struts, those at the top being as much as 80 feet in length, of 13-inch square pitch-pine, were extended from various points on the wall to recesses cut in the floor, *Fig. 3.* The lower end of each strut rested against a 9-inch by 3-inch foot-block, bedded in the recess. Between the strut and the foot-block were placed a pair of folding wedges for tightening. The upper row of four struts, which were inserted before the dumpling excavation commenced, ran through to the wall. The lower struts, on the other hand, which were fixed at the same time as the inner sheeting, pressed against outside walings that laced it together. The longer struts were supported by one or two 12-inch by 4-inch props, and were tied down by $\frac{5}{8}$-inch chains to short pieces of old rail buried in the concrete floor. These prevented the struts from falling or rising under pressure. It was intended to fix horizontal laces to prevent lateral movement, but few were inserted, as the struts were found perfectly rigid. In all, twenty-seven struts were used to maintain the exposed section of wall, 120 feet long and 49 feet high. They performed their work well, and at no time showed signs of distress. The wall was carefully watched, but, in spite of the great pressure of water upon it (at times some 2,600 tons), no movement occurred.

With a view to despatch, it had been specified that the ship caisson which was to form the dock-gate should be erected close to its final position; it was accordingly built about 6 feet outside and $3\frac{1}{2}$ feet above its keel-blocks, *Fig. 3.* By the end of June, 1895, it was sufficiently near completion to be moved home. This work was successfully accomplished by Messrs. Rennie and Company, the builders. The water was then admitted between the inner sheeting and the caisson by turning the discharge-trough of the contractor's drainage-pumps into this space. At first, when the caisson was not fully ballasted, the water was kept low to avoid floating it up, but when the caisson was completed, it was allowed to rise to low-water level, *Fig. 4.*

On the 7th June, 1895, blasting was commenced on the wall. The miners worked in pairs, one holding a $1\frac{1}{8}$-inch steel drill, while the other struck with a 7-lb. hammer. The holes were sunk to a depth of 2 feet to 3 feet, and about 4 feet apart. They

were fired at meal-times (three times per shift) with ½ lb. of powder, or with 2 ozs. of gelignite. Each hole drilled caused the removal of about 25 cubic feet of concrete. Another gang cut away the loose concrete, and shovelled it into skips, which were lifted by the cranes overhead, and were emptied into tip-wagons. The service roads were supported on the sheetings and intermediate piles, *Fig. 4.* The total quantity of concrete removed by this process was about 2,500 cubic yards. The work occupied 7½ weeks, night gangs being employed for the greater part of that time. As the wall was broken away, and the short struts to the sheetings were consequently released, long struts stretching across from front to back were substituted to take the water-pressure, *Fig. 4.* These were tightened with folding wedges, and were kept in position with puncheons and laces, like ordinary trench struts. To avoid risk

Fig. 4.



Cross-Section on X X, *Fig. 1.*

of the piles floating while this work was in progress, about 200 tons of pig-iron, &c., were stacked on the inner and outer sheeting. Leakage water was removed from the box by the same pumps which had served when fixing the struts to the outer sheeting. The water was always kept 1 foot or 2 feet lower than the concrete wall surface. Sealing material was thrown outside and inside of the sheeting, which proved fairly tight on the outer side. The inner sheeting, however, allowed some water to pass. The water in the Empress Dock was generally higher than that in the graving-dock entrance, *Fig. 4;* the whole of the "box" was, therefore, tilted slightly towards the graving-dock. This caused a slight parting between the upper and lower sills of the inner sheeting and admitted some water, which was reduced by clay puddle packed by divers. The entrance corners were trimmed

to a true curve, *Fig. 1*, a brick facing was built to them between the coping and low-water level, and the wall was cut away to a depth of 33 feet below the coping-level. This depth was reached at the end of July, 1895.

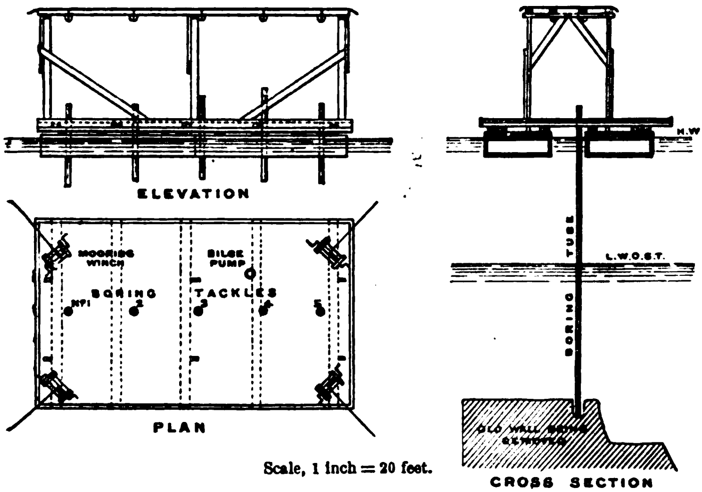
At this point it was determined to stop all work, as it had been arranged that H.R.H. the Prince of Wales should open the dock on the 2nd August, and that a vessel should be repaired in it immediately afterwards. Accordingly the next week was spent in removing the temporary works. The enclosure was flooded by opening sluices on the 26th July, the pumps having been previously removed. The two cranes then removed the rails and pig-iron which had been used for top weight. Then, working from the middle, the cranes lifted the roads and cross-timbers on which they had rested. This work occupied about 2 days. Meanwhile two grab cranes, mounted on barges, removed the sealing material which had been thrown down in front of the outer sheeting. The top waling, which was bolted to the piles, was cut across at about every 5 feet, as it was impossible to draw the bolts. A powerful tug was then engaged to pull away the outer sheeting. Working from one end, a chain was fastened round four or five piles at a time and was connected to the tug, which was started forward again and again till they were free. Those piles which were lightly driven came out easily, but some which had penetrated 15 feet or so were drawn with difficulty and, in one or two cases, broke off. The piles being removed, the struts and walings floated up. Several boats and a small tug were ready to take the floating pieces to the timber pond. The inner sheeting was easily removed by the same method.

The last day of the week was spent in testing the depth to see that there was no obstruction above the entrance level, fixed temporarily at 27 feet below high water. A tide-gauge was first set up on the adjoining wall, the zero of which was 27 feet below high water. The test was then made by dragging over the entrance a length of 35-lb. rail, 24 feet long, suspended by $\frac{3}{4}$-inch chains from two boats placed side by side. Each chain was hung over a small jib in the stern of the boat, and was provided with tallies at every foot to show the depth of the rail below the water-level. The chains were lowered out until both ends of the rail were the same depth below water, and the boats were taken along tracks parallel to the new dock-walls. The tracks were arranged to overlap 5 feet or so to avoid any obstruction being missed. One boat was hauled along a line stretched between the caisson and an anchor correctly laid in the Empress Dock. The other

was kept abreast of it with the oars. Whenever the rail came to a standstill or appeared to drag, a diver was sent down to find the obstruction, and it was promptly removed.

On the 2nd August, 1895, the opening ceremony was performed, and shortly after the steamships "Paris" and "St. Louis" were successfully docked. The work of removing the old wall was then resumed, this time by means of submarine blasting. A raft 33 feet long and 18 feet wide was moored over the wall, *Figs. 5.* It was formed by two parallel pontoons, fixed at a clear distance of 3 feet 6 inches from each other, which space was bridged by the deck planking. This planking was pierced by five vertical openings

Figs. 5.



Scale, 1 inch = 20 feet.

about 6 feet apart, through each of which passed boring tackle. The tackle consisted of a 6-inch steel tube, screwed together in lengths of 3 feet, reaching from the borehole to the decking of the raft. Inside this tube, the boring tool was worked, generally a steel chisel, 4 inches wide, attached to several lengths of 1¼-inch square bar also screwed together. This tool was "jumped" by a gang of four men. The débris was cleared out with a pump auger in the usual way, the tackle for lifting the tools being fastened to the roof of the raft. As the hole was sunk, the tube followed down. At first, each borehole was sunk only 2 feet or 3 feet, and the raft was shifted to a fresh place; but it was found more profitable to remain in one position for the day, in which case

the holes generally reached a depth of 5 feet. The five tools were worked simultaneously, and at the end of the day the holes were fired one by one. Each charge consisted of 10 ozs. of gelignite packed with a detonator into a tin case and attached to a waterproof fuse long enough to occupy 10 minutes in burning. The boring tools having been lifted out, the fuse was lighted, and the case was lowered by a long line to the bottom of the borehole. The boring tube was then drawn up to 5 feet or 6 feet clear of the concrete surface, so that the explosive should not damage it. Little disturbance was noticed on the raft, but inside the caisson at the dock-entrance the shock was felt severely. On the following day the raft was moved to a new position—generally 3 feet from the last one—and the process was repeated. Special care had to be taken when blasting at each end of the opening, not to undercut the entrance walls. The tubes in this case were pitched by a diver, on those portions which required removal. In all four hundred and ninety-six shots were fired, and 1,992 lineal feet of hole were bored to remove the 1,350 cubic yards of concrete that remained in order to gain the full depth of 37 feet 6 inches below high water of spring tides. To remove the blasted concrete, a ladder-dredger capable of working in 24 feet of water was employed, and also a single-chain floating grab, both filling into hoppers and barges alongside. The dredger was useful to lift the concrete after it was first blasted, while the grab moved the heaps which collected in corners where the dredger could not reach. The latter machine was more effectual in the open, however, as the grab somewhat shirked the hard material unless it was first broken up. This was sometimes done by repeatedly dropping on to the concrete with the crane a pile monkey armed with heavy steel chisels. One machine or the other was at work nearly the whole time that the blasting proceeded—the raft working at one end of the wall and the dredger or grab at the other. Owing to frequent interruptions for docking ships, &c., the work was not finally completed until January 1896.

The work was carried out under the direction of Messrs. Galbraith and Church, MM. Inst. C.E., Engineers to the London and South Western Railway Company, by Messrs. Lucas and Aird, Contractors. The engineers were represented at Southampton by Mr. Maurice F. G. Wilson, M. Inst. C.E., and the contractors by Mr. William Colson, Assoc. M. Inst. C.E.

The Paper is accompanied by two drawings and three photographs, from which the *Figs.* in the text have been prepared.

(*Paper No. 3028.*)

"Notes on the Timbers of the Province of Minas Geraes, Brazil."

By Reginald James Hinton, Assoc. M. Inst. C.E.

The following notes have been compiled after ten years' experience in the use of the timbers mentioned. Near railways, pitch-pine can now be obtained, which is cheaper and easier to work than most of the native woods, but for many purposes native timber is preferable. The weight, in pounds per cubic foot, is estimated from seasoned specimens of the more rare varieties, but by actual weighing of 1 cubic foot of the commoner kinds of timber. The strength has been arrived at by the following method. A piece of the wood, 12 inches long by 1 inch square, is supported at the extremities, and is then loaded in the middle until it breaks. By this means a "constant" is obtained from which the breaking-weight, in pounds, of any piece can easily be calculated. If the piece is to be loaded in the middle, for instance, the formula $\frac{D^2 \times W \times K^1}{L}$ may be used, where D is the depth of the piece in inches; W, the width in inches; K, a "constant" for various woods; and L, the length of the piece in feet. A piece of pitch-pine under this test broke with a weight of 607 lbs., but a piece of *Paroba* (Vermelha) required 1,376 lbs.; therefore, taking pitch-pine as 1·00, *Paroba* (Vermelha) would be 2·26 times as strong (see Appendix); and 607 and 1,376 are the constants in lbs. for pitch-pine and *Paroba* (Vermelha) respectively.

All large logs are barked and roughly squared in the forest, and are then loaded on bullock carts with one end of the log trailing on the ground, and are so transported many leagues. Great loss is sustained by the owners from the wearing away of the end by dragging on the ground, and many a fine log is depreciated considerably in value by the time it reaches its destination; but it is useless to devise means to prevent this, as the natives insist upon doing as their fathers did before them. The natives, also, instead of cutting when the sap is down, cut at certain phases of the moon, no matter at what time of year. The names of the timbers differ a little in some localities, but those of the chief woods given are known throughout the province.

[Appendix.

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APPENDIX.

Name of Timber.	Weight in Lbs. per Cubic Foot.	Strength, Pitch-Pine being taken as 1·00.	Constant.	Remarks.
Angá. Colour, brown . . .	47	..	..	Of good appearance, but brittle, and rots quickly. A timber to be avoided. Logs up to 120 cubic feet.
Angelim (Doce). Colour, grey. .	41	1·24	756	A fair wood of medium quality, useful for uprights, and stands exposure to wet and dry weather. Logs up to 150 cubic feet.
Aroeira. Colour, tawny with red markings.	79	2·18	1,328	The heaviest wood in the province. Valuable for all wearing surfaces, such as brake-blocks. Stands wet or dry weather. Logs small, about 30 cubic feet.
Balsamo. Colour, reddish brown .	59	..	..	A pleasant-scented wood and good for any purpose, but uncommon. Logs up to 50 cubic feet.
Brauna (Parda). Colour, tawny .	66	2·88	1,751	An exceedingly strong timber, nearly three times as strong as pitch-pine. Splendid for uprights or wall-plates of frame-houses. Stands wet or dry weather; much prized for "sets" in timbering the levels of mines. Logs up to 100 cubic feet.
Brauna (Preta). Colour, black .	64	2·60	1,584	Not quite as good as Brauna Parda, but very valuable for the same purposes. Logs up to 100 cubic feet.
Cabiuna. Colour, red and black in streaks and patches . . .	63	1·88	1,144	Commonly called Rosewood. Very pretty for furniture and turned articles; hard and durable, and has been used for timbering a mine. Stands wet as well as any wood. Logs up to 100 cubic feet.
Candeia. Colour, nearly white .	63	2·43	1,478	The best timber possible for small "setts" in water-levels, or for filling in behind big timbers in mines; very tough and durable. Logs up to 15 cubic feet, but a good-sized stick would be about 7 inches diameter at the butt and 20 feet long.

Name of Timber.	Weight in Lbs. per Cubic Foot.	Strength, Pitch-Pine being taken as 1·00.	Constant.	Remarks.
Canella (De Velho). Colour, nearly white . . .	..	..	..	Capital for pick and hammer handles when split, not sawn. It grows about 6 inches in diameter, the section showing three wings which split off easily.
Cangerana. Colour, brown . . .	44	..	..	The male cedar. To be avoided except for common cigar-boxes. Logs up to 60 cubic feet.
Cedro. Colour, brown . . .	39	1·00	607	This is the well-known cedar. A valuable scented wood for patterns, clothes-chests, &c.—in fact, until 1890 it was the only wood used for patterns. It will be noticed that the strength is the same as that of pitch-pine. Logs up to 100 cubic feet.
Coita Carvalho. Colour, grey. .	48	..	..	A good light wood that may be turned very thin without splitting. Has been used successfully for wooden legs. Logs up to 50 cubic feet.
Cycupira. Colour, varies . . .	55	..	..	Tough good timber, useful for axles of bullock carts. Logs up to 40 cubic feet.
Folha de Bolo (Vermelha). Colour, red	55	2·00	1,214	Valuable for general purposes; the grain is long and fibrous and fairly good to work. May be depended upon either on the surface or underground, either wet or dry. Logs up to 130 cubic feet.
Folha de Bolo (Branca). Colour, nearly white or light brown . .	56	2·24	1,364	Much the same as Folha de Bolo (Vermelha), but closer grain; a splendid timber. Logs up to 130 cubic feet.
Gonçalo Alves. Colour, white and red streaks . .	69	..	..	A strong durable hard timber, suitable for uprights or cross-pieces. Logs up to 100 cubic feet.
Ipé. Colour, green and dark markings	63	2·44	1,487	A hard, strong, valuable wood, used for teeth of mortise wheels and guides, &c. Logs up to 50 cubic feet, but not straight for many feet. It has proved a splendid wood for blocking pulleys of wire-rope transmission plant.

Name of Timber.	Weight in Lbs. per Cubic Foot.	Strength, Pitch-Pine being taken as 1·00.	Constant.	Remarks.
Iacaranda (Taõ). Colour, tawny with black specks and dashes . .	62	2·33	1,416	The best wood for teeth of mortise wheels, and anything where a strong wearing-surface is required. Logs up to 40 cubic feet. It is of more uniform quality than Ipé.
Iatobá (Vermelha). Colour, red . .	63	1·87	1,135	A deceptive wood. At one time thought highly of, but has proved to rot in a dangerous manner. It may be to all appearance sound and yet hollow in places. It is a timber to be avoided. Logs up to 150 cubic feet.
Iatobá (Branca). Colour, nearly white and light brown . . .	58	2·39	1·451	Much stronger than Iatobá (Vermelha); may be used where it will be always dry, but must be carefully selected. Logs up to 100 cubic feet.
Iequitibá. Colour, reddish brown .	41	..	..	To be avoided. It yields good planks for temporary work, but very soon decays. Logs up to 150 cubic feet.
Landim. Colour, brown . . .	59	..	..	Good durable wood for general purposes. Logs up to 100 cubic feet.
Moreira. Colour, yellow . . .	58	Varies considerably		Very similar in appearance to Vinhatico, but different in quality. Some pieces are too brittle to be of much use, but it makes nice handles for turning tools and other small articles. Other pieces may be very tough, even as much as 2·49 times as strong as pitch-pine. Logs up to 30 cubic feet.
Paroba (Vermelha). Colour, reddish-pink	48	2·26	1,376	The finest timber in the province for general purposes. Close grained and comparatively easy to work. Good for surface or underground, either in or out of water. Logs roughly squared sometimes contain as much as 200 cubic feet.
Paroba (Branca). Colour, nearly white. . . .	43	..	..	A very useful wood, but inferior to Paroba (Vermelha). Logs up to 150 cubic feet.
Tamboril. Colour, reddish brown .	45	..	..	Nice grained wood, good for plank and general purposes. Logs up to 120 cubic feet.

Name of Timber.	Weight in Lbs. per Cubic Foot.	Strength, Pitch-Pine being taken as 1·00.	Constant.	Remarks.
Tinta. Colour, dark red	58	..	..	Very good for making planks for flumes or launders, but its weight makes it awkward to carry.
Vinhatico. Colour, yellow . . .	42	1·25	774	Soft, easily worked wood. Good for furniture, buckets of water wheels, flumes, or launders, but should be always either wet or dry, never subject to change. Very wasteful wood, much sap, and planks split badly, but it is common and therefore much used. Logs up to 150 cubic feet.
Vinhatico (Rajado). Colour, yellow with dark markings	52	1·60	976	A superior and harder wood than the common Vinhatico and beautifully marked.

The following timbers are used occasionally, but the Author has not had much experience of their use :—

Name.	Weight in Lbs. per Cubic Foot.	Remarks.
Bagré	50	Very fair timber.
Cabui	59	Nice grained hard wood, similar in appearance to Gonçalo Alves.
Cachoá	55½	
Camboatá . . .	58	Mistaken sometimes for Angá, but it is quite a different wood, hard and durable in water, though rather brittle; not to be trusted with much weight.
Canella (Loura) . ,, (Amarella) ,, (Preta) . ,, (Vermelha)	47	All fairly good wood.
Capebano	..	
Massaranduba . .	53	Good for plank and general purposes.
Oleo (Vermelho) .	54	Both good timber, strongly scented. They exude oil long after being dressed.
,, (Copaiba) .	61	
Pindaíbuna . .	62	Very good, almost the same as Brauna (Preta) and same colour.
Sassafrass . . .	50	Scented wood; good for making boxes.

OBITUARY.

JAMES ABERNETHY, born on the 17th May, 1844, was the eldest son of Mr. James Abernethy,[1] Past-President. After being educated at Bruce Castle School, Tottenham, he was articled to his father in 1860, and subsequently served a pupilage at the Elswick Works of Messrs. Sir W. G. Armstrong and Company (now Messrs. Armstrong, Whitworth and Company). On the expiration of his pupilage he was employed by that firm for a year on the Birkenhead Docks. He then entered his father's office, and from 1868 to 1875 acted as Resident Engineer on a division of the works of the Alexandra Docks and Railway at Newport, Mon. During the last twenty years he was in his father's office and acted as a general assistant in designing and inspecting works; but his somewhat indifferent health prevented him from taking a really active part in the business. He died at Margate on the 30th May, 1897. Mr. Abernethy was elected an Associate on the 7th December, 1869, was subsequently placed among the Associate Members, and was transferred to the class of Members on the 25th March, 1879.

ROBERT DUNDAS, son of James Dundas, iron merchant in Dundee, was born on the 31st December, 1838. He was educated at the High School of Dundee, on leaving which he resided for a time with a relation, who was an extensive farmer in the Carse of Gowrie, where he gained a knowledge of agricultural matters which was afterwards useful to him. He left in 1858 and became a pupil of Mr. Charles Ower, Harbour Engineer, Dundee, with whom he remained till September 1863, during which time a large new dock was constructed. He then entered the office of Messrs. B. and E. Blyth, of Edinburgh, and was engaged in parliamentary work, and in staking out, preparing plans for and superintending the construction of railways.

In October, 1866, Mr. Dundas was appointed principal assistant to Mr. George Graham, Chief Engineer of the Caledonian Railway

[1] Minutes of Proceedings Inst. C.E., vol. cxxiv. p. 402.

Company, under whom he was engaged on the maintenance of the line, and also on various new works till 1871, when a resident engineer was required for the Glasgow and Paisley, and Glasgow, Barrhead and Kilmarnock Joint Line, owned jointly by the Caledonian and Glasgow and South Western Companies, to which post he was appointed. He carried out extensive additions to those railways, and under his charge the Glasgow and Paisley line was widened and large goods stations were constructed. In 1880 he was appointed Resident Engineer of the Southern Division of the Caledonian Railway, latterly having over 500 miles under his charge, with an exceptionally heavy traffic on some parts of the line. Many additions were carried out under his superintendence.

Mr. Dundas was President of the Institution of Engineers and Shipbuilders in Scotland for two Sessions, 1891–93, and was also President of the local Association of Students of the Institution at Glasgow during the Session 1889–90. He attended faithfully to his work and made it a point to know all the details. On the Golf Links at Troon, where he enjoyed his only relaxation and holiday, he was a familiar figure, and there he showed the energy and enthusiasm which were characteristic of him in his daily duties. He was seized with inflammation of the liver in London in 1896, from the effects of which he only partially recovered. He died at Blane House, Bothwell, on the 28th June, 1897. He was elected a Member on the 1st December, 1874.

ROBERT FOGG was born on the 9th September, 1822. After serving a pupilage of seven years under Mr. Isherwood, mechanical engineer, of Leigh, near Manchester, he entered the service of the Egyptian Government, as Engineer in charge of the construction of reservoirs, public buildings, &c. On returning to England he was from 1849 to 1851 charged with the design and erection of cotton factories near Preston. From 1852 to 1855 he was in Russia, employed by Messrs. Baird on the erection of a bridge across the Neva, and by the Volga Steam Navigation Company as an Assistant Engineer. In 1855 he returned home, and for two years had the management of the Drawing Office at the Regent's Canal Ironworks, for the late Mr. Henry Grissell.[1]

In 1857 Mr. Fogg was appointed Manager of the London business of Messrs. Cochrane, Grove and Co. (now Messrs. Cochrane

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[1] Minutes of Proceedings Inst. C.E., vol. lxxiii. p. 376.

and Co.), which post he retained until his death on the 13th August, 1897, at his residence, Silverdale, Knight's Hill, West Norwood. Since 1868 he was, in addition, in practice as a Consulting Engineer, and was for some years employed in preparing designs for bridges, steamers, barges, &c., for the Egyptian Government, and for other similar works in this country.

Mr. Fogg was elected an Associate on the 1st December, 1863, and was transferred to the class of Members on the 24th February, 1885.

JACOB FORREST was born on the 11th May, 1830, at West Rainton, Durham. He served his time as a mechanical engineer on the Stockton and Darlington Railway, and subseqnently was engaged under his father in the erection of pumping and other machinery for water and gasworks at various towns in the North of England. At Maryport he married Jessie, daughter of the late Mr. James Wise, of Wigton and Aspatria, and in May, 1852, proceeded to Spain as agent for Mr. George Mold, the contractor for the Isabel II. Railway, in whose service he remained five years. From 1857 to 1863 he was engaged in carrying out a contract for a length of 60 miles of the Great Northern Railway of Spain, and in 1865 he returned to England.

Mr. Forrest then became connected with various colliery enterprises in North Wales and in the Midlands. In 1867 he opened out the Oak Pits Colliery, carried on by a Joint Stock Company, of which he was the Managing Director and Chairman. He also became a Director of the Wedgwood Coal and Iron Company. In 1882 Mr. Forrest again proceeded to Spain, and eventually settled at Salamanca as Engineer for Messrs. Pearson and Sons on the Portugal and Madrid Direct Railway. There he was engaged until his death on the 3rd February, 1897. Mr. Forrest enjoyed a high reputation among the Spaniards for being a man of his word, and was an intimate friend of Senor Sagasta and other ministers, who were always ready to assist his enterprises. He was elected an Associate on the 13th January, 1874, was subsequently placed among the Associate Members, and was transferred to the class of Members on the 10th January, 1882.

NATHANIEL GREW, born on the 6th October, 1829, served his pupilage at the Fairfield Engineering Works, London, under the late Mr. W. Bridges Adams, from 1846 to 1849. He was then employed on the South Eastern Railway in London and at Ashford until 1851, when he proceeded to Spain and was engaged for two years on the survey and setting out of the Albacete-Almansa section of the Madrid and Valencia Railway. From 1854 to 1859 he was Chief Assistant to Sir William Siemens,[1] by whom he was employed on work in connection with various improvements in iron and steel manufacture and in engines and furnaces.

In 1860 Mr. Grew began to practise on his own account. He became Consulting Engineer to several large firms of merchants and for many years was engaged in advising as to the supply of materials for railways in Argentina, Central America, Peru and Brazil. The last important work with which he was connected was the Produce Market at Bahia Blanca, Argentina, for the Bahia Blanca and North Western Railway Company. He had only just inspected at Glasgow the material for that work on the day when he was seized with his fatal illness. Mr. Grew died at his residence, Clarence House, Belmont Park, Lee, on the 11th July, 1897. He was elected an Associate on the 6th March, 1860, and was transferred to the class of Members on the 6th April, 1897.

ALFRED HOWARD VINCENT NEWTON, fourth son of the late Mr. William Edward Newton, Civil Engineer, was born in London on the 13th January, 1852. After being educated at King's College, Strand, where he gained the Daniell Chemical Scholarship, he was articled to his father, and was subsequently employed by Major-General Scott, R.E.,[2] to carry out experiments in connection with sewage works at Leeds, Bolton and Nottingham. In 1877 he was appointed Assistant Engineer to the Singapore Municipality, which post he held for nineteen years. During that time he was in charge of the Department for periods aggregating about four years; and between March, 1895, and June, 1896, owing to the illness of Mr. James MacRitchie,[3] he carried on the work of the office single-handed. Among the works upon which he was engaged may be mentioned the erection of iron and steel bridges over various rivers and creeks in Singapore, drainage

[1] Minutes of Proceedings Inst. C.E., vol. lxxvii. p. 352.
[2] *Ibid*, vol. lxxv. p. 318. [3] *Ibid*, vol. cxxii. p. 374.

and reclamation works, water-supply and public buildings. By permission of the Municipal Commissioners he erected several buildings in Singapore, and designed bridges for private firms. During the year 1886, while on leave, he visited the principal engineering works in Victoria and New South Wales, and for six months studied bridge construction and the testing of materials at the University of Sydney.

In 1896 Mr. Newton was appointed Acting Deputy Executive Engineer for Waterworks by the Municipality of Bombay. On his retirement from Singapore the Municipal Commissioners passed the following resolution:—"That this Board place upon record their appreciation of the services rendered to the Municipality of the City of Singapore by Mr. Howard Newton, as Assistant Engineer, during his long service, and desire to thank him for the energy and zeal with which he has carried out the duties entrusted to him.—29 July, 1896." Mr. Newton died of cholera at Bombay on the 27th July, 1897. He was elected an Associate Member on the 6th April, 1880, and was transferred to the class of Members on the 2nd March, 1897.

FRANCIS GOOLD MORONY STONEY, who died at Neuenahr, Germany, on the 7th August, 1897, in his sixty-first year, was chiefly known as the inventor of the rolling sluice, and as an engineer who made sluice design in all its branches his special study. He was the son of Mr. Thomas G. Stoney, J.P., and was born at his father's house, Arran Hill, co. Tipperary, on the 5th April, 1837. His engineering education was received at Queen's College, Belfast, and he was subsequently articled to Sir John Macneill,[1] who was then engaged on the construction of railways in Ireland. Even at this date Mr. Stoney showed a preference for the mechanical side of the profession, and, after some years with Sir John, he became manager of the Dundalk Ironworks. In May, 1865, he entered the service of Messrs. John Elder and Co., the Clyde shipbuilding firm now known as the Fairfield Company. During the years 1865 and 1866 he represented the firm in Peru, in connection with the construction and working of the Callao Floating Dock. After returning home he again left England for India in April, 1868, this time on railway work in the service of Mr. E. W. Barrett, contractor for the north-

[1] Minutes of Proceedings Inst. C.E., vol. lxxiii. p. 361.

west portion of the Madras Railway. About a year later he entered the service of the Madras Navigation and Canal Company as personal assistant to the Chief Engineer, Mr. J. H. Latham; and it was the experience of Indian irrigation requirements gained during this time which first turned his attention to the designing of sluices.

In 1869 Mr. Stoney was at work on the design of a double-door sluice, but, his health breaking down, he was obliged to return to England and was practically invalided for the two following years. During this period of ill-health, however, he continued to think out the problems suggested in India, and in 1872 he was in correspondence with General Mullins, R.E., Chief Engineer for Irrigation, Madras, respecting an equilibrium sluice to work under 100 feet head, which was the subject of his first patent, and also some smaller sluices of 36 feet area. Early in 1873 he invented and patented the cylindrical sluice which was afterwards used on the River Weaver Navigation. A model was sent to Mr. J. W. Sandeman, Engineer to the Weaver Trust, in February of that year; and, subsequently twenty-eight of these sluices were ordered. Before their manufacture had been completed Mr. Stoney's third sluice was invented and patented. This design, which covers the well-known "roller sluice," proved a far better solution of the problem than either of the preceding inventions, and has had more extensive practical developments.

During this time Mr. Stoney was acting as Chief Draughtsman to Messrs. R. B. Bell[1] and D. Miller,[2] of Glasgow. His health again breaking down, he resigned that appointment and devoted all his energies to advocating the new sluices. In August, 1876, he started as a Consulting Engineer in Westminster, where he remained for about ten years. During part of that time he was in partnership with Mr. Ellice-Clark. The record of those years is one of constant effort to introduce the roller sluices. Other work, however, was done, and in 1878 Mr. Stoney obtained a prize of £100 for his design for a steam-ferry between Greenwich and Poplar. He also designed a pier for Hove, and in 1880 brought out a steel sleeper in conjunction with the late Mr. R. C. Rapier.[3] About that time a patent was obtained for a "double-door roller sluice," an absolutely watertight contrivance rendering it peculiarly suitable for graving-docks. Mr. Stoney also patented a form of rolling flap-valve, which has been used in tidal outfalls, for

[1] Minutes of Proceedings Inst. C.E., vol. lxxv. p. 293.
[2] Ibid, vol. xcvi. p. 322. [3] Ibid, vol. cxxix. p. 389.

sewage work, &c. The first large roller sluices were erected for the Lough Erne Drainage[1] in the summer of 1883. The sluices were four in number, each 29 feet by 16 feet, and were worked individually by hand or by a turbine. Roller sluices of this type were used throughout on the Manchester Ship Canal to the number of about thirty large flood sluices and eighty lock sluices. These sluices were manufactured by Messrs. Ransomes and Rapier, for which firm Mr. Stoney had become manager in February, 1887.

The publicity given to the sluices by their use on the Manchester Ship Canal resulted in an increasing demand during the last ten years. The total number of sluices constructed from the designs of Mr. Stoney is about 180, representing a sum of £230,000. Among the chief may be mentioned the Rhone sluices at Geneva, where there are six gates, each 10 metres wide by 8 metres high, the Richmond sluices across the Thames, and the Glasgow sluices across the Clyde now in course of construction. The type of sluice used in these last two sets formed the subject of a sixth patent and is of a most ingenious character. The gate is lifted by a trunnion at each end placed at the exact centre of gravity. While in the water it moves in a vertical plane in the usual manner and in contact with the rollers, but on being lifted to the required height it is automatically swung round on the trunnion into a horizontal plane, thus saving much headroom. The Richmond sluices are 66 feet wide and 10 feet deep, while those for Glasgow are 80 feet wide by 12 feet deep, and the working of the sluices is so satisfactory that there is no reason why even this great size should not be exceeded. Large sluices are also in contemplation for India and Egypt, and there is every reason to believe that the greatest developments of Mr. Stoney's inventions and of the work to which he devoted his life are yet to come.

In his capacity as Works Manager for Messrs. Ransomes and Rapier, Mr. Stoney engaged in the design of steam-cranes, and introduced several improvements. The most important of these are the patent tipping-cranes, a number of which were used in connection with the dredging operations on the Manchester Ship Canal and also for the loading of coal. Mr. Stoney was elected a Member on the 6th March, 1883, and while practising in Westminster frequently attended the meetings of the Institution.

[1] Minutes of Proceedings Inst. C.E., vol. ci. p. 73.

ARTHUR GRAEME OGILVIE, second son of Mr. Alexander Ogilvie,[1] of Sizewell House, Leiston, Suffolk, was born on the 31st January, 1851. He was educated at Rugby School and at Trinity College, Cambridge, where he graduated in the Natural Science Tripos in 1873. He then served a pupilage of three years to Sir George Elliot, Bart.,[2] during which time he was occupied at the Powell Duffryn, Horncastle, Usworth and Buldick Collieries. Mr. Ogilvie obtained the Government certificate for competency to manage mines, and was for a time Assistant Engineer at the Pensher Colliery.

In 1878 Mr. Ogilvie took an office at No. 4 Great George Street, Westminster, and from that date practised as a Mining Engineer. He was for some years, and at the time of his death, Chairman of the Powell Duffryn Steam Coal Company and a Director of the New Russia Company. In 1892 he contested the Sudbury division of Suffolk in the Liberal interest, but failed to secure the seat. Mr. Ogilvie died at his residence, 8 Grove End Road, St. John's Wood, on the 29th July, 1897. He was elected an Associate on the 6th March, 1877, and was subsequently placed in the class of Associate Members.

ALFRED LOUIS SACRÉ was born in London on the 16th April, 1841. At the age of sixteen he was articled to the late Mr. Archibald Sturrock, of the Great Northern Railway Company's Locomotive Works at Peterborough, where he subsequently became foreman of the Carriage and Wagon Department. He was then for three years chief locomotive manager of the Peterborough district of the Company's system. About the year 1865 Mr. Sacré was appointed to the charge of the Yorkshire Engine Company, of which he became later Managing Director. The works, situated at Meadow Hall, near Sheffield, were designed and erected under his direction.

In 1871 Mr. Sacré joined the Avonside Engine Company, of Bristol, as manager, which post he held for six years. In 1877 he commenced to practise as a consulting engineer in London. About the year 1882 he became manager of the Vacuum Brake Company, of which he was appointed later Managing Director.

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[1] Minutes of Proceedings Inst. C.E., vol. lxxxvi. p. 373.

[2] *Ibid*, vol. cxvi. p. 355.

He continued to conduct the business of that Company until his death, which took place at his residence, 3 South Villas, Camden Square, N.W., on the 25th July, 1897. Mr. Sacré was elected an Associate on the 2nd February, 1869, and was subsequently placed in the class of Associate Members.

FRANK WALTER SCOTT, Junior, was born in London on the 3rd November, 1864. After being educated at Worthing and at King's College, Strand, he was articled in 1881 to Messrs. Langen and Hundhausen, engineers, of Grevenbroich in the Rhine Province. In 1884 he entered the firm of Messrs. George Scott and Sons, engineers, of Christian Street, E., of which his father is the head. He was subsequently placed in charge of the drawing office, and in June, 1888, became a partner in the firm. He was an indefatigable worker, and took the keenest interest in all matters connected with the profession. He designed and constructed a gas-compressing plant at the Royal Institution and made several improvements in hydraulic machinery. Ill health, caused by overwork, compelled him to give up business, and he died at Totland, in the Isle of Wight, on the 22nd July, 1897. Mr. Scott was elected an Associate Member on the 14th January, 1890.

JAMES BREND BATTEN, the well-known solicitor and parliamentary agent, of Great George Street, Westminster, died on the 26th August, 1897, at Homburg, at the age of sixty-seven. Born at Plymouth in 1830, and educated at Millhill School, he was articled to his uncle, Mr. Winterbotham, a solicitor of Cheltenham, and almost immediately on being admitted a solicitor, became associated as manager with the firm of Messrs. Swift and Wagstaff, of Liverpool and Westminster. He was soon after appointed solicitor to the town of Liverpool, and had the satisfaction of winning in the House of Lords the great rating case of the "Mersey Board *v.* Jones," which brought the whole area of the Liverpool Docks into rating for the relief of the poor. From 1853 Mr. Batten was prominently employed in railway work. He was also a director of the Plymouth and Dartmoor Railway and of the Sambre and Meuse Railway in Belgium. At the general election of 1892 he unsuccessfully contested Shrewsbury

against the present member, Mr. H. D. Greene, Q.C. He married the sister of the late Sir Evan Morris of Wrexham, with whom he had been associated in railway work in the district.

Mr. Batten was elected an Associate on the 2nd May, 1865.

CHARLES TOWNSHEND CASEBOURNE was born in Caledon, co. Tyrone, on the 28th June, 1836, his father, Mr. Thomas Casebourne,[1] who was connected with the Institution so long ago as 1828, being at the time engaged as Engineer to the Ulster Canal Company during its construction. In 1845 he removed with his parents to West Hartlepool, on his father accepting the appointment of Engineer to the West Hartlepool Harbour and Dock Company. He was educated at Stockton Grammar School, and subsequently entered the office of Messrs. Thomas Richardson and Sons, engine builders, of Hartlepool. After two years he entered the employment of Mr. William Hutchinson, contractor, under whom he was engaged for ten years in the construction of the docks and harbour of West Hartlepool. He also acted in the same capacity on the construction of the Cleveland Railway.

In 1863, in conjunction with Mr. Albert Lucas, Mr. Casebourne established cement works at West Hartlepool which have since been successfully carried on. The firm was formed into a limited company in 1882, of which Mr. Casebourne was the Chairman and Managing Director until his death on the 17th May, 1897.

A few years ago Mr. Casebourne became interested in the salt industry of South Durham and discovered a valuable deposit in the neighbourhood of Greatham, near West Hartlepool. He subsequently erected extensive works for the West Hartlepool Salt and Brine Company. Shortly afterwards he put down a borehole in the neighbourhood of Seaton Carew, to ascertain whether coal was to be found in the district, but the deposit was not found to be of sufficient thickness to be profitably worked. Some later borings undertaken by him, in conjunction with the Vivian Exploration Company, in the neighbourhood of Castle Eden proved entirely successful. Mr. Casebourne married, in 1862, the third daughter of Mr. Samuel Baslow, by whom he had eight sons and two daughters. He was elected an Associate on the 7th April, 1868.

[1] Minutes of Proceedings Inst. C.E., vol. xxiv. p. 527.

LIEUTENANT-GENERAL SIR WILLIAM FRANCIS DRUMMOND JERVOIS,[1] G.C.M.G., C.B., F.R.S., Colonel-Commandant Royal Engineers, died on the 17th August, 1897, at Bitterne Court, Hants, from the effects of a carriage accident. He was the eldest son of the late General Jervois, and was born at Cowes, in the Isle of Wight, in 1821. He was educated at Dr. Burney's school at Gosport, and at Woolwich Academy, and entered the Royal Engineers in 1839, becoming Captain in 1847, brevet Lieutenant-Colonel in 1861, Colonel in 1872, Major-General in 1877, and Lieutenant-General in 1882. For seven years from 1841 he was actively employed at the Cape of Good Hope. In 1842 he acted as Brigade-Major in an expedition against the Boers, and during the three following years was professionally engaged at various frontier stations, making roads, building bridges and establishing military posts. In 1845, having been appointed acting Adjutant to the Royal Engineers, he accompanied the Chief Engineer over the whole frontier of the Cape Colony and the settlement of Natal, and in the earlier part of 1846 he was Major of brigade in the garrison of Cape Town, until the arrival of Sir Henry Pottinger as Governor and of Sir George Berkeley as Commander-in-Chief, with whom he proceeded to the frontier against the Kaffirs. During the Kaffir war he made a military survey and map of Kaffraria, a work of great difficulty in the midst of the military operations. In 1852, he was ordered to the island of Alderney for the purpose of designing plans for the fortifications and the superintendence of their execution, a work strongly advocated by the great Duke of Wellington. In 1854 he was promoted to the rank of Major, and in 1855 he was transferred to the London District and was nominated by Lord Panmure a member of a Committee on Barrack Accommodation, the labours of which contributed much to the improvements that have of late years been effected in the construction of barracks as well as in the sanitary condition of the troops.

In 1856 Major Jervois was appointed Assistant Inspector-General of Fortifications under Sir John Burgoyne,[2] and on the appointment in 1859 of a Royal Commission to report upon the defences of the country, he was selected by the Government to be secretary.[3] He was at the same time secretary to the Permanent Defence Committee, under the presidency of the Duke of Cambridge.

[1] This Notice is reprinted, with slight modification, from *The Times* of the 18th August, 1897.

[2] Minutes of Proceedings Inst. C.E., vol. xxxiii. p. 192.

[3] The Report of this Commission is in the Library of the Institution.

He became the confidential adviser of Lord Palmerston and of several Secretaries of State on matters relating to defence, and designed the fortifications of Portsmouth, Plymouth, Pembroke, Portland, Cork, the Thames, the Medway, and other places. During long service, of nearly twenty years in the War Office, he was also a member of the Special Committee on the Application of Iron to Ships and Fortifications. In 1861 he attained the rank of Lieutenant-Colonel, in 1862 was appointed Deputy Director of Fortifications, and in 1863 was nominated a Companion of the Bath and was sent on a special mission to report on the defences of Canada, Nova Scotia and New Brunswick, on which occasion he visited the fortifications at the principal ports on the seaboard of the United States. In 1864 he was sent again on a special mission to Canada to confer with the Canadian Government on the question of the defence of the Dominion. On his return to England, his report was laid before Parliament, and the Imperial Government undertook to carry out the defences of Quebec on the plan recommended by him. He was also sent on special missions to Bermuda, Halifax (N.S.), Malta and Gibraltar, and planned improvements and additions to the fortifications of those places. In 1871–72 he was ordered to India to advise the Government of India respecting the defences of Bombay, Aden, the Hooghly and other places. He was created a Knight Commander of the Order of St. Michael and St. George in 1874, and was appointed Governor of the Straits Settlements in 1875. He held the latter post for two years and during that period he quelled a formidable insurrection in the Malay Peninsula. The subsequent prosperity and quiet of the Malay States resulted mainly from this action. In April, 1877, he was appointed to advise the Governments of the Australian colonies on the defence of their chief ports. He was then selected to be Governor of South Australia. He was promoted to G.C.M.G. in 1878, and in December, 1882, he was appointed Governor of New Zealand, where, on his advice, the fortification of the principal ports was undertaken by the Colonial Government.[1] Throughout his stay in Australasia, till the year 1889, he continued to be the chief adviser of the Governments there on matters relating to defence. Since his retirement from the public service in 1889, he strenuously advocated that naval stations and coast defences should be handed over to the Naval Department. He was elected an Associate on the 3rd February, 1857.

[1] See his pamphlet "The Defences of New Zealand," Library Inst. C.E. Tracts folio, vol. 35.

*** The following deaths have also been made known since the 31st July, 1897:—

Member.

BEWICK, THOMAS JOHN; *died* 29 August, 1897.
O'MEARA, THOMAS FRANCIS; *died* 9 September, 1897.
WILSON, ALLAN; *died* 13 August, 1897.

Associate Member.

HEWSON, JOHN; *died* 26 July, 1897.

Associate.

MUNDAY, GEORGE JAMES; *died* 20 September, 1897.

Information as to the professional career and personal characteristics of the above is solicited in aid of the preparation of Obituary Notices.—SEC. INST. C.E., 30 *September*, 1897.

SECT. III.

ABSTRACTS OF PAPERS IN SCIENTIFIC TRANSACTIONS AND PERIODICALS.

Topographical Surveys. J. L. VAN ORNUM.

(Bulletin of the University of Wisconsin, Engineering Series, 1897, p. 331.)

The Author gives details of the area, scales, contour intervals, and cost per square mile of the topographical surveys of the United Kingdom, India, France, Sweden, Russia, Germany, Austria, Switzerland, Italy, Belgium, Spain, United States (Coast and Geodetic Survey, Geological Survey, Great Lake Survey, Mississippi River Commission Survey, Mexican Boundary Survey, Croton Watershed Survey, Philadelphia Water Department Survey, Connellsville Coke Region Survey, and the District of Columbia Survey). He also gives details of the surveys made for topographical purposes by the cities of St. Louis and Baltimore.

Tracing the history of surveying instruments and methods, he gives an illustrated account of the original plane-table invented by Johann Prætorius in 1590, translated from Daniel Schwenter's "Treatise on Practical Geometry," published at Nuremburg in 1667. This instrument is practically identical with the modern plane-table. Credit for the first application of the tacheometric principle in surveying is generally given [1] to William Green, who was awarded a premium for its invention by the Society of Arts in 1778. In the same year the Danish Academy of Sciences gave a prize to G. F. Brander for a similar device which he had applied to his plane-table six years before. The Author shows, however, that its real discoverer was James Watt, who used it in 1771 for measuring distances in the surveys for the Tarbert and Crinan canals. In James Patrick Muirhead's "Life of James Watt," is found the statement by Watt himself that he contrived the instrument in 1770, and that in 1772 he showed it to Smeaton. Though England thus gave the principle to the world at this early date, it was first extensively used in Italy in 1823. Its use spread to Switzerland in 1836, and eventually to almost all Europe for topographical and railway surveys. It was taken to the United States from Switzerland by J. R. Mayer in 1848, and its first extensive use in that country was on the survey of the Great Lakes.

B. H. B.

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[1] "Treatise on Mine Surveying," by Bennett H. Brough. London, 6th edition, 1897, p. 223.

Magnetic Observations in Geological Mapping. H. L. SMYTH.

(Transactions of the American Institute of Mining Engineers, 1897, p. 640.)

In mapping the pre-Cambrian rocks, particularly the iron-bearing formations of Algonkian and Huronian age, in the Upper Peninsula of Michigan, the Author found the use of simple magnetic instruments indispensable, and in a Paper covering sixty-nine pages he has recorded the results of his experience in tracing magnetic rocks by means of the disturbances produced in these instruments. The results are given in systematic form with such references to the particular area as are necessary in order to illustrate general principles. The most striking phenomena exhibited by the pointings of the magnetic needles when the disturbing formation had a north and south strike and a vertical dip, are the convergence of the horizontal needle towards the rock for a considerable distance on each side; the occurrence of two points of maximum deflection of the horizontal needle corresponding to each direction of convergence; the occurrence of one point of no deflection of the horizontal needle, midway between these maximum points; and the coincidence of the point of maximum dip with the point of no horizontal deflection. The points of maximum and zero deflection of the horizontal needle must correspond to maximum and zero values of the horizontal component of the rock-force. The phenomena in the case of a magnetic rock having a uniform strike in any direction and a vertical dip, and in the case of a rock having a uniform strike and dipping at any angle, are also described. The phenomena observed are so completely in in accord with theoretical deductions that the following practical conclusions may be regarded as established:—(1) The strike of a magnetic rock is given by the line joining the points on successive traverses at which the dip angles are a maximum. When the rock is vertical this line of magnetic attraction lies in the middle plane of the rock and fixes its position. (2) The dip of a magnetic rock is towards the nearer horizontal maximum. (3) The thickness of the magnetic formation must, if buried, always be less than the distance between the maximum points. In conclusion, the Author gives, as an example of magnetic methods in unravelling the geology of a favourable region, an account of his results and of the steps by which they were reached in the area between the Marquette and Menominee iron districts in Michigan.

B. H. B.

The Structure of Cement Mortar and Concrete. A. MARTENS.

(Mittheilungen aus den königlichen technischen Versuchsanstalten zu Berlin, 1897, p. 89.)

In this Paper the Author considers the structure of cement mortar and concrete, in so far as it is determined by the physical properties of the cement, sand, gravel, stones, and the water used for mixing. Chemical action is not discussed. Considering the largest pieces in the concrete to be spheres of unit radius touching one another, the size and number of the spheres required in succession to fill up the vacant spaces is investigated.

A. S.

The Testing of Roman Cements in Accordance with the Austrian Standards.[1] KARL BERGER.

(Mittheilungen des k. k. technologischen Gewerbe-Museums in Wien, 1897, p. 166.)

Exception having been taken by Mr. Tarnawski to the standards laid down by the Austrian Society of Engineers and Architects, the Author shows that, to one who has an intimate acquaintance with the Roman cements prepared in Austria, the stipulated tests will not appear too high, and can be easily attained in the case of by far the larger proportion of samples. With regard to certain cements rich in clay which set at first somewhat slowly, and which consequently fail to attain the prescribed strength in seven days, it is pointed out that they greatly improve when tested at twenty-eight days, and that the seven-day test is only to be considered as a check upon the uniformity in quality of the material as delivered. The adulterations practised by manufacturers are not due to the attempt to reach abnormally high tests, but are occasioned by the desire to counteract the injurious action of the free lime. With regard to the method of testing adopted, the assertion that no indication is thereby afforded of the behaviour of the cement after the lapse of months or years can only be met by the statement that cements which satisfactorily undergo the tests laid down are those which prove to be the best in the long run. The proposal that chemical analysis should be resorted to is open to many difficulties, which are discussed by the Author, and it is asserted that, in the present state of our knowledge of cement-action, the tests which are based upon certain easily-ascertained physical properties are preferable to chemical ones, though it is possible that the normal tests are capable of improvement.

G. R. R.

[1] Minutes of Proceedings Inst. C.E., vol. cxxviii. p. 370.

The Testing of Natural Stones. M. Gary.

(Mittheilungen aus den königlichen technischen Versuchsanstalten zu Berlin, 1897, p. 46.)

This Paper gives, in tabular form, the results of all experiments made on natural stones at the Royal Testing Laboratory, Berlin, during the official years 1892–3 to 1894–5. The absorption of water, the compressive strength, dry, saturated with water, and after exposure to frost, and the resistance to wear are the principal properties investigated.

It seems that sandstone, granite, and marble lose strength by saturation with water to a greater extent than other stones, while sandstones and granite are those which are most affected by frosts.

A. S.

Testing of Artificial Asphalt. M. Gary.

(Mittheilungen aus den königlichen technischen Versuchsanstalten zu Berlin, 1897, p. 74.)

This Paper gives an account of tests of an artificial asphalt manufactured by Messrs. Fritz, Zoeller and Wolfers, Berlin, from coal-tar, sulphur, chloride of lime, and blast furnace slag, and pressed into plates of 10-inch, 5-inch, and 2-inch thickness under hydraulic pressure of 200 atmospheres. For comparison, tests of similar plates of Sicilian natural asphalt were also made. As the artificial asphalt is intended for street-paving, the tests related to resistance to pressure at different temperatures from 15° C. to 80° C.

At high temperatures the artificial asphalt is slightly superior to the natural, while at ordinary temperature it offers more than twice the resistance to pressure.

A. S.

The Strength of Blue Fir-Wood. M. Rudeloff.

(Mittheilungen aus den königlichen technischen Versuchsanstalten zu Berlin, 1897, p. 1.)

At the instance of the Ministers of Public Works and of Agriculture the Royal Testing Laboratory undertook an investigation of the strength of fir-wood which had become blue by exposure to air and moisture, and a comparison with the strength of white fir-wood.

The manner of cutting the test specimens is described in detail.

Tests were made of the absorption of water by air-dried wood. The greatest part of the absorption took place within twenty-four hours of immersion, though absorption was not quite completed at

the end of twenty-one days. The blue wood showed a smaller absorption than the white. The absorption was greater the higher the original position of the wood in the tree-trunk.

The swelling of the wood due to absorption of water increased until twenty-one days' immersion, though the greater part took place within twenty-four hours. The swelling in a direction tangential to the annual rings is greater than that in a radial direction, while that parallel to the axis of the trunk is least. The tangential and radial swellings are smaller the higher the original position of the wood in the trunk, while the axial swelling is greater. The density decreases with increasing height in the trunk. The phenomena presented by the shrinking of the green wood during air-drying agrees with that of the swelling due to absorption of water.

The compressive strength is not reduced on the wood becoming blue, but, on the contrary, the blue is slightly stronger than the white wood. This holds for air-dried and for water-saturated wood. The strength of the saturated wood is less than 50 per cent. that of the air-dried.

The Paper contains numerous Tables, diagrams, and photographic reproductions, and ends with a short discussion of the nature of the 'blueing' of fir-wood.

A. S.

The Results of Tensile Tests. O. Knaudt.

(Zeitscrift des Vereines deutscher Ingenieure, 1897, p. 1115; Stahl und Eisen, p. 619; Annalen für Gewerbe und Bauwesen, 1897, p. 84.)

Messrs. Schulz Knaudt bought three mild steel plates, 40 inches by 80 inches by 0·6 inch, from Messrs. Thyssen & Co., Mulheim, Hoerder Bergwerks- und Hüttenverein, and Fried. Krupp, Essen, respectively, each plate being specified to have a tenacity lying between 21·5 tons and 25·5 tons per square inch (34 kilograms to 40 kilograms per square millimetre), and a minimum extension of 25 per cent. They also made a fourth plate to the same specification at their works in Essen. From each place nine tension specimens were prepared, of which two were tested by Messrs. Kruft, Essen, two sent to the mechanical laboratory of the Technical High School at Munich, two sent to the Royal Testing Laboratory at Charlottenberg, Berlin, two sent to the Polytechnikum at Zürich, while the ninth was preserved for reference. Some of the test specimens were straightened cold, others heated before straightening.

The figures obtained from the four different testing machines are compared. As regards the tensile strength, the smallest difference in the figures referring to any one plate was 0·9 kilogram per square millimetre, the largest difference 4·9 kilograms per square millimetre, and the average difference 2·0 kilograms

per square millimetre. Leaving out of account the cold-straightened specimens tested at Munich, which showed greater variation in the strength of the four plates than did the specimens tested elsewhere, the greatest and average differences are 2·1 kilograms and 1·2 kilogram per square millimetre respectively (1·34 ton and 0·76 ton per square inch respectively). As regards the extension before fracture, the greatest, least, and average differences are 9·1 per cent., 2·5 per cent., and 4·4 per cent. respectively; while leaving the specimens tested at Munich out of account, these differences are 3·7 per cent., 1·3 per cent., and 2·9 per cent. respectively.

Specifications for mild steel plates often give 6 kilograms per square millimetre difference between the higher and lower limits for tenacity, but since from the above experiments the best testing machines may show a variation of 2·1 kilograms per square millimetre, the difference the steel works have to come and go upon is reduced to 1·8 kilogram per square millimetre (1·15 ton per square inch). A. S.

The Results of Tensile Tests. A. MARTENS.

(Zeitschrift des Vereines deutsche Ingenieure, 1897, p. 1116.)

The method of comparing testing machines by carrying out tests on specimens cut from the same piece, as described above [1] by Mr. Knaudt, is by no means the best. But if this method be adopted, the greatest care must be taken to eliminate as far as possible irregularities in the material tested. Round bars (not plates) should be used, and at least ten specimens of each material should be allotted to each testing machine. From such experiments an estimate of the reliability of the investigation can be formed.

But the above procedure cannot give any information as to the absolute accuracy of any one of the testing machines used, especially as the variations in the material itself are usually far greater than 1 per cent.

Prof. Martens quotes a number of the recommendations of the Royal Testing Laboratory, Charlottenberg, as to the testing of materials of construction, which are not observed in Mr. Knaudt's investigations, and which therefore lead Prof. Martens to disagree from Mr. Knaudt's final conclusion. He remarks, however, that investigations like these are of great practical value, and their publication in the highest degree praiseworthy, as more attention will then be paid to the calibration and control of testing machines, which are now used as much as the balance in adjudicating upon *meum* and *tuum*. He then describes the methods of calibrating the testing machines at Charlottenberg. A. S.

[1] See previous abstract.

Methods of Conducting Bending-Tests at Low Temperatures.

M. RUDELOFF.

(Mittheilungen aus den königlichen technischen Versuchsanstalten zu Berlin, 1897, p. 114.)

In a previous Paper[1] the Author described some investigations on the influence of cold on the strength of iron and steel, the tests being made with the hydraulic press. The results for rivet-iron and wrought-iron bar did not agree closely with those described by Steiner,[2] his tests being made with falling weights. It was therefore decided to investigate the influence of the method of testing on the results obtained, and for this purpose tests were made on wrought iron, Siemens-Martin steel, and basic mild steel, at temperatures of 20° C., – 20° C., and – 80° C., (*a*) with the hydraulic press, (*b*) with falling weights.

Tests were made on plain and on notched bars, and the results are analysed fully. The conclusions the Author arrives at are that the tests on notched bars are most suited to show the influence of cold on the toughness of these metals, and that the methods of testing with the hydraulic press and with falling weights give no appreciable difference in the results.

A. S.

Preliminary Experiments on the Wires and Strands of Wire Rope. M. RUDELOFF.

(Mittheilungen aus den königlichen technischen Versuchsanstalten zu Berlin, 1897, p. 137.)

These experiments were made to determine the behaviour of the wires and strands of wire rope when subjected to bending or rolling and tension, and also the influence of the strength of the wire on the durability of the rope.

The material was supplied by the Westphalian Union Iron and Wire Company, and consisted of four kinds of wire of specified tensile strengths, 24 tons, 32 tons, 51 tons, and 76 tons per square inch respectively; the wires each being 2 millimetres (0·08 inch) diameter. From these, two-, three-, and four-wire strands without core were made in the Royal Testing Laboratory; and also four- and six-wire strands with copper core. The experiments on single wires consisted of tensile tests, repeated bending to a radius of 0·2 inch, and repeated bending to various radii while subjected to tension. The experiments on the strands were tensile tests and repeated bending while subjected to tension.

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[1] Mittheilungen aus den königl. techn. Versuchsanstalten, 1895, p. 199.
[2] Wochenschrift des österr. Ing.- und Architekten Vereines, 1891, p. 290.

Two out of the four kinds of wire showed considerable variation in tensile strength. The resistance to repeated bending (as measured by the number of bendings) while under tensile stress, diminished very rapidly as the tensile stress increased from zero to 2½ tons per square inch; the decrease in bending resistance with further increase of tensile stress took place much more slowly. As regards the four different kinds of wire experimented on, this decrease of bending resistance with increase of tensile stress took place more rapidly, the smaller the tenacity and the greater the ductility of the wire.

The law of the variation of the number of bendings with the radius of curvature and the tenacity of the wire can be represented by a surface of which the principal radii of curvature at any given point are of opposite signs.

The strands made from the 24-ton wire attained a maximum strength with a pitch of 8 inches to 12 inches; the strands made from the higher tenacity wires were stronger the greater the pitch. The resistance of the strands to bending, when subjected to a tensile stress of about one-tenth the ultimate strength, was greater the greater the tensile strength of the wire. The resistance to repeated bending of a single wire was found to be far less than that of a strand made from the same wire.

A few experiments were made on old pit ropes and on some new ropes.

The Paper is accompanied by numerous Tables and diagrams.

A. S.

Experiments on the Frictional Resistance of Riveted Joints.

SCHRÖDER VAN DER KOLK.

(Tijdschrift van het koninklijk Instituut van Ingenieurs, 1895–96, pp. 136 *et seq.*; Zeitschrift des Vereines deutscher Ingenieure, 1897, pp. 739 *et seq.*)

These experiments were designed with a view to determine the degree of influence exerted by frictional resistance under varying conditions on the strength and general efficiency of riveted joints, with particular reference to the exigencies of railway bridge design. Reference is made to the recent researches of Considère,[1] of Bach,[2] and of Dupuy,[3] and the Author indicates the details in which his own experiments are more complete, and the methods of measurement of stress and strain more accurate than is the case in the researches of his predecessors. The majority of the specimens tested were butt joints with a strap on each side secured by four

[1] Annales des Ponts et Chaussées, 1886, vol. ii. p. 5.
[2] Zeitschrift des Vereines deutscher Ingenieure, 1892, p. 1141; 1894, p. 1231; and 1895, p. 301.
[3] Annales des Ponts et Chaussées, 1895, vol. ix. p. 5.

single rivets. The plates and straps were of the same width and carefully machined. In the middle of the edge of each plate and strap and along the pitch line of the rivets on both sides, small holes were drilled into which little three-cornered rods were inserted. To these the two types of measuring gear were attached which admitted of the extension of each plate from rivet to rivet being measured as well as the relative distortion of the rivet itself. Measurements were taken at regular increments of load in kilograms per square millimetre (0·635 ton per square inch) of rivet area. The extensometers could be read, the Author states, accurately to one ten-thousandth of an inch.

The experiments were divided into five groups:—

I. In this set of tests the straps were of the same thickness as the plates and riveted, four rivets.

II to V. In these sets the straps were half the thickness of the plates. In set II and set IV the specimens were secured by four rivets; in set III and set V by six rivets. Sets II and III were hand-riveted; sets IV and V were riveted by a hydraulic riveter.

Plates and straps were of wrought iron, 2·61 inches broad, from $\frac{1}{2}$ inch to 1 inch thick. The diameter of the holes was between $\frac{3}{4}$ inch bare and $\frac{3}{4}$ inch full, and the pitch of the rivets was 3·15 inches in specimens with four rivets, and 2·6 inches in the specimens with six rivets.

Particular attention was paid to the riveting, which was always carried out under proper supervision. Five specimens were prepared for sets I to III, and in some of the specimens compared in these groups the rivet-holes were carefully rimered out, and the rivets, when heated to a cherry-red, fitted so well that considerable force was required to drive them home. The object of this was to get as solid a joint as possible in order to form a basis of comparison with the behaviour of other joints in sets IV and V, in which the rivet-holes were purposely bored with varying diameters. Generally the scheme of the experiments was to determine:—

(1) The influence of the temperature of the rivet.

(2) The influence of a conical thickening under the rivet-head where closed.

(3) The influence of too large holes.

(4) The influence of continued pressure after closing.

It must be understood that the division into groups only has reference to the relative thicknesses of the plates and straps. In groups I and II, for example, there were specimens prepared with well-fitting and badly-fitting holes. The main results of the experiments are as follow:

The amount of permanent set is considerably reduced by continued pressure, and the load at which permanent set is first observed is increased. The effect of giving the rivet-holes a slightly larger diameter than the rivets was, without exception, to increase the load at which any relative movement of the plates and straps was observed.

A very complete Table of results is compiled, from which the Author draws the following conclusions:

The elastic relative movement of plates and straps is not proportional to the load on the joint, but is dependent rather upon the frictional resistance of the plates and straps.

The resistance to tension is made up of friction between the plates and the shearing strength of the rivets. When the load is removed, the strained rivets can only regain their original form by overcoming this plate-friction, and the greater this friction, the less will the rivet get back to its original state. From the graphic results quoted in the Paper it is seen that where the rivets have been a loose fit in the holes the frictional resistance in the hand-riveted specimens is greater—although the permanent set is also greater—than in the specimens in which the rivets fitted the holes exactly. The increase in frictional resistance is not so marked in the specimens in which the straps were thicker than the plate. Hydraulic-riveted specimens approached very nearly in their behaviour to those in which the rivets fitted the holes exactly. Experiments showed that repetitions of load did not cause any decrease in the frictional resistance. The ultimate strength of the joints was not investigated.

It is curious and important that a joint in which the rivets exactly fit their holes should turn out to be the least satisfactory from the bridge-builder's point of view. It would appear from the results of these experiments that the most favourable result is obtained—in hand-riveting—when the rivets are originally a loose fit in the holes, and when the strap is half the thickness of the plate.

E. C. S.

The Use of Earth Centres for Arches. C. van Bogaert.

(Annales de l'Association des Ingénieurs sortis des Écoles spéciales de Gand, 1896–97, p. 110.)

In the alterations of the East Antwerp railway-station, two masonry arches were erected on earth centres, the earth—a clayey sand—being rammed in 20-inch layers to the shape of the arch, and to wooden templets, and covered with 1½-inch planking. The first arch was on sunk abutments, with a span of 103 feet 5 inches, reduced to 78 feet 9 inches by walls along each side, and with a width of 90 feet 5 inches, to be increased hereafter to 231 feet. The curve of the intrados was a compound one, and the arch was 41·33 inches thick at the crown, and 137·79 inches at the springings. It was constructed in separate voussoir-sections 16 feet 5 inches long, the whole width and thickness of the arch, consisting of a stone facing, backed with hard bricks, all in cement mortar. At the springing, for a length of 40 inches, and at three other places, a strip the whole width and thickness of the arch

was laid in dry with slips of wood and oakum in the joints. After the whole of the arch had been laid, these strips were taken out and relaid in mortar. This was done to prevent cracking of the arch should the centering settle during the laying. The earth centre was formed ½ inch higher than specified, but after the first sections from the springings had been laid, it was found advisable to raise the centre a further 3 inches. After the temporary portions had all been made good, the centering was removed, a tunnel, 16 feet 5 inches wide, and 6 feet 7 inches high, being first driven through, and the material then removed symmetrically in layers from each side. Plates of lead, 0·3 inch thick were inserted, 20 inches wide at the springs inside, and 12 inches wide at the crown outside, to allow of a possible movement at these points. The cost of the centering amounted to nearly 4*s.* per square yard of intrados. The second arch was smaller, being only 39 feet 4½ inches span, with a rise of 5 feet 3 inches, but at an angle of 56° 8′ with the faces. Here the stone was all laid in dry; the joints being then quickly filled with mortar, and the brick backing laid in. The centering was removed in the manner described for the first arch.

Another arch, with a span of 59 feet, was constructed in a similar manner to the first arch, but on wooden centres. In replacing the dry strips at one of the springings, however, too long a portion was removed at a time, and the centres settled under the weight more than an inch. The work was quickly replaced, with no further damage than some fifty stones spalled on the face, and having to be made good, and a small crack near the springing where the settlement originated. The Author considers that these experiences prove the utility and economy of earth centres, especially in the case of large spans where the system of separated voussoir-sections is adopted. The Paper is illustrated.

R. B. M.

The Alexander III. Bridge over the Seine at Paris.

A. Dumas.

(Le Génie Civil, 26 June, 1897, p. 129.)

This bridge will join the Esplanade des Invalides to the new avenue near which will be the proposed Palais des Beaux-Arts, and the foundation stone was laid on the 7th October, 1896. It will consist of fifteen cast-steel ribs, pivoted at the centre and the abutments, the total span being 352 feet 8¼ inches between centres of pivots and 357 feet 10 inches clear between the abutments, the rise between side and centre pivots being 20 feet 7 inches. The abutments will be sunk on caissons under compressed air, 26 feet to 30 feet below water-level to a bed of sand, and the lower portion will be of cement concrete with masonry in cement mortar above. The bridge crosses the river at an angle of

83° 38′; the intermediate ribs are of rolled joist section, the outer ones being more ornamental. The width of the flanges is 23½ inches, and the depth near the centre pivot is 29½ inches. Each half rib is in fifteen lengths, bolted together; the roadway is carried on plates and cross-girders and the footways on corrugated floor plates, all supported on verticals from the ribs or on the ribs themselves at intervals of 11 feet 10½ inches. The minimum height of the roadway above the under side of the ribs is only 37½ inches, and there is also a horizontal and diagonal cross-bracing between the verticals. The roadway has a width of 65 feet 7 inches, and the footways on each side are 32 feet 10 inches wide. The height from the under side of the ribs to ordinary water-level is 26 feet 6 inches. The balustrade is of cast iron, and the ornamentation of the bridge is of a very florid description. The article is illustrated by a view of one of the abutments now under construction, another of the bridge as it will appear when complete, a sheet of details and two other diagrams.

R. B. M.]

The Queen Carola Bridge, in Dresden. HERMANN KLETTE.

(Zeitschrift für Architektur und Ingenieurwesen, Hannover, 1897, p. 313.)

This bridge across the Elbe was commenced in August 1892 and opened for traffic in July 1895, there being already in existence three other bridges across the river in Dresden.

The Paper is illustrated by ten photogravures, which include a general view of the structure from upstream, a view of portion of an arch, and nearer views of particular portions of the ironwork, also views of the masonry of a pier, of the balustrading, lamps, &c., showing the artistic details, as well as more distant general views of the structure and overhead staging during progress of construction. There is also a lithographed sheet, giving an elevation of the upstream face, a longitudinal section, and plan of the bridge, and on the same sheet are five cross-sections, showing the piers and abutments, all to a scale of $\frac{1}{500}$.

The length of the structure is 500 metres (1,640 feet), of which 188 metres (617 feet) pertain to the main-stream openings, 94 metres (308 feet) and 48 metres (157 feet) to the flood openings on either side, and 170 metres (558 feet) to the inclined approaches. Commencing on the Altstädt, or left bank of the river, there are two arches of masonry of 21·48 metres (70 feet 6 inches) and 21·76 metres (71 feet 5 inches) span, the intervening pier being 4·54 metres (14 feet 10 inches) thick. The next pier is 8·02 metres (26 feet 4 inches) thick, and is followed by the main-stream arches of Siemens steel, three in number, two of which are each 52·25 metres (171 feet 6 inches) span, and the centre one of 55·75 metres (183 feet) span between piers (the span between the hinged skew-backs of these arches is 50 metres

(164 feet) and 52·9 metres (173 feet 6 inches) respectively). The two intervening masonry piers are each 5·95 metres (19 feet 6 inches) thick. On the right bank, or Neustädt side, is a pier of 8·02 metres (26 feet 4 inches) thick, followed by four flood arches of masonry with spans of 20·33 metres (66 feet 9 inches), 20·2 metres (66 feet 3 inches), 19·75 metres (64 feet 9 inches), and 19·75 metres (64 feet 9 inches) respectively, with two intervening piers of 3·1 metres (10 feet 2 inches) and 5·10 metres (16 feet 9 inches) thickness. The grade of the approaches towards the bridge crown is 1 in 72. The versed sine of the main-span arches is only about $\frac{1}{13}$ of the span. The width between parapets is about 16 metres (52 feet 6 inches). There is a very detailed Table of cost of the whole work from foundation to completion.

	Marks	£	s.	d.
Cost of the structure itself	2,483,324	124,166	4	0
Cost for staging, trial borings, plant, &c.	841,676	42,083	16	0
	3,325,000	166,250	0	0

D. G.

Widening of Gertraudt Strasse and Reconstruction of the St. Gertraudt Bridge, Berlin. F. Eiselen.

(Deutsche Bauzeitung, 1897, pp. 293 and 305.)

The eastern extension of Leipziger Strasse crosses a navigable arm of the River Spree 59 feet wide. The old bridge was 26 feet wide, sufficient only for one line of tramway, while the traffic was constantly increasing. The new bridge, 62 feet wide, was opened for traffic in December 1895. It is an arch of 59 feet span and about 6 feet rise, built of basaltic lava, 20 inches thick at the crown and 23 inches at the springing, the thickness at the crown, including asphalted felt concrete and wood blocks, being 27¼ inches and the clear headway for navigation 10 feet 10¾ inches. In order to keep the navigation open with 9 feet 11¼ inches headway during construction, the centering was constructed as a steel cantilever bridge with a central girder 13 feet long and 9½ inches deep, leaving 2 inches for planking. The cost of the bridge is about £11,600, but for the undertaking as a whole, 5,680 square yards of house property were bought at an average price of £49 per square yard; three-fourths of this was, however, available for subsequent sale. The architecture of the bridge is simple, almost the only ornament being a bronze group of St. Gertraudt, by Professor Siemering.

M. A. E.

Collapse of a Bridge over the Adour at Tarbes. A. D.

(Le Génie Civil, 31 July, 1897, p. 209.)

The railway bridge at this place was carried away by a flood on the 3rd July, and in order to allow of a speedy resumption of traffic the Southern Railway Company asked the military authorities to lend them one of the "Marcille" bridges, which are kept for war purposes. This was agreed to, and the bridge was completed on the 17th July and tested, with the approval of the military authorities, according to regulations. The first test with a stationary load was satisfactory, but when the regulation train of two locomotives followed by loaded trucks was crossing, and as the second locomotive neared the centre, the bridge collapsed. Fortunately no one was killed.

The Adour bridge has a span of 147 feet 7½ inches, and thus required the largest size of "Marcille" bridge. This consisted of two plate girders, 7 feet 2½ inches deep, spaced 4 feet 11 inches apart, with the road on the top; the girders being in sections bolted together with cross-bracing between. The total weight was 6·6 tons per lineal foot, the material being mild steel. The bridge failed by buckling sideways at the centre. These military bridges were designed for a maximum stress of 7·62 tons per square inch, before the present testing regulations came into force. The article is illustrated by seven views of the bridge—three taken after the accident, and one with the test-train on, just before the bridge collapsed—and a load diagram of the test-train.

R. B. M.

The Steam-Ferry Arrangements at Schiewenhorst, Mouth of the Vistula. Müller and Rudolph.

(Zeitschrift für Bauwesen, 1897, p. 397.)

The new cut of the Vistula is crossed at Schiewenhorst, among the sand-dunes of the coast, by the main road leading from Danzig to Stutthof on the Frische Haff. The traffic on this road is considerable, and demanded the construction of such an arrangement for the transport of vehicles and passengers as could be maintained in constant service day and night, unbroken in its continuance excepting at periods of exceptional ice-flow. The stream is here 400 metres (436 yards) broad. The distance of the site of the ferry from the open sea is 1·2 kilometre (¾ mile), and is subject to the violence of the wind from the north and north-east quarters. In addition to this, in winter a heavy ice-flow has to be contended with. In the lower stretches of the river an ice-breaker is maintained by the fiscal authorities to keep clear a channel for the off-flow of the ice, and thus, sometimes for months, the river is

rendered uncrossable, and the only means for getting from bank to bank would formerly have been by the up-country Dirschau bridge.

The Paper is illustrated in the text by a plan of the river at the site of the ferry and of the right bank landing-place, also diagrams of the landing-stage in elevation and cross-section. In the atlas accompanying the journal is a large plate, giving details of the landing-stages, and a plan, longitudinal section, and cross-sections of the ferry-boat. The length of the latter is 24 metres (78 feet 9 inches), the breadth 8 metres (26 feet 3 inches), the depth 2·9 metres (9 feet 6 inches), and draught, fully laden, 2 metres (6 feet 6 inches). The bow and stern are alike, each end being fitted with rudder and screw-propeller. The steering is by steam- or hand-power. The boat is of such strength and so built as to be capable of use as an ice-breaker. The course taken by the vessel in crossing is a curve convex downstream, and the landing-stages are laid out conformably with this curve.

D. G.

The Machinery and Working of the Lock at Einlage, Mouth of the Vistula. A. Rudolph.

(Zeitschrift für Bauwesen, 1897, p. 379.)

To diminish the effects of floods, and especially of the ice-flow in the winter season, a cause formerly of frequent bursting of the river-bounding dams and consequent damage to the adjacent fertile low-lying lands, the main outlet channel of the Vistula has, in its lower portion, been diverted and thereby shortened about 10 kilometres (6¼ miles). By the cutting-off of the stream-flow from the old stream course below the point where the new cut commenced, arrangements had to be made for connecting the latter with the now still-water portion, or Danzig Vistula, and its navigation from the town of Danzig. These arrangements are here described, and include a short canal and lock for vessels, and a narrower canal and lock for rafts. These are parallel with one another, but distinct throughout their length, and stretch across the narrow neck of land dividing the old stream course from the cut.

The Paper is illustrated in the text by a general map of the district, a general plan of the arrangement of canals and locks, also details of sluice-valves, &c., and a plan of the lock, showing the positions of the machinery and arrangements for working the lock-gates, swing-bridge, &c. In the atlas accompanying the journal are two large plates of details of the lock, lock-gates, accumulator, and other hydraulic machinery, and of the pumping-engines.

D. G.

Groynes and Sea-Coast Defences. A. T. WALMISLEY, M. Inst. C.E.

(Industries and Iron, 1897, vol. xxii. p. 379.)

Where properly designed and constructed, groynes are of great value in the retention of beach necessary for the protection of cliff, foreshore, or sea-wall from the encroachment of the waves. As a rule they should be directed towards the prevailing dangerous wind, and if the coast suffers from both directions, should be provided with land-ties on either side. When the uprights are formed of double steel rails with intervening timber the Stilgoe pile point will save the labour of welding the rails. As concerns boarding, the Author prefers to use a combination of longitudinal and diagonal boards, in order to prevent the formation of holes, and to tie the groyne well in.

It is important to carry groynes well out into low water and tie them effectually at the head to some form of embankment; carrying the groyne well, up into the full of the beach, so that the sea and not the beach may wash over the top in rough weather, being essential to success.

In the case of a sea-wall the provision of groynes prevents the waves from scooping away the beach at the base and thereby acquiring a greater power of attack than when breaking on a sloping shore, as was evidenced at Sandgate, Hove, and Romney.

Where the cost of a sea-wall on low uncultivated shores cannot be undertaken, double rows of faggot bundles, 6 feet long and 3 feet in girth, set endwise at a depth of 3 or 4 feet in the full of the beach, will make an efficient barrier to connect the groynes.

The best method of retaining shingle without hindering the flow of water is by building the groynes low at first and raising them as the beach increases in height, a good example of which method is shown at the Dymchurch wall, Romney Marsh, where double uprights are set (7½ feet apart between centres) in concrete, and the 9-inch by 3-inch boards, constituting the groynes, laid horizontally, fresh layers being added as the sand, &c., accumulates.

At Bognor and Littlehampton the timber groynes, 300 feet long and 500 feet apart, are placed in a slanting direction from the prevailing winds, but the general opinion is that most beach is retained when groynes are laid square to the line of greatest wind force, the waves then spending their force chiefly on the groyne, and so piling up shingle on the beach instead of scooping it out.

Of course groynes sometimes have ill effects, due to excessive accumulation on the windward side only, and for this reason all points of view should be considered in appointing their situation and direction to the foreshore.

C. S.

A Caisson for repairing the Dock-walls at Calais.

CHARGÉRAULD.

(Annales des Ponts et Chaussées, 1897, p. 298.)

This caisson was used for repairs in the Carnot basin of the Calais docks, where the mortar facing of the east wall had deteriorated. The caisson was open at the top and on the side next the wall, rectangular in plan, 19 feet long and 7 feet 10½ inches wide, and 28 feet 10½ inches high, being deep enough to reach from the bottom of the wall to above water-level. It was entirely of metal, with the exception of timber at the bearing edges, the actual contact with the masonry being by means of a strip of soft wood, and a hemp roll. The sides next the wall were the exact contour of the wall, and the caisson had two air-tight compartments, by filling or exhausting which it could be sunk or floated as required. Where necessary the face of the wall was prepared with a strip of cement to receive the bearing edges, and when in place the body of the caisson was pumped dry by a centrifugal pump from a barge alongside. During work inside the caisson, the leakage was kept down by a small pulsometer pump.

The wall was refaced with stone blocks averaging 16 to 32 inches long, 11¾ inches thick and 17¾ inches from face to back, set in cement mortar, and filled in behind with concrete. The capital cost of the apparatus was about £1,170, and the cost of refacing, exclusive of capital charges, was 56 shillings per square yard, the average thickness removed being 3 feet 1 inch. The Paper is illustrated by two sheets of details.

R. B. M.

The Raz-Tina Lighthouse. REGNOUL.

(Annales des Ponts et Chaussées, 1897, p. 252.)

This lighthouse is situated off the port of Sfax, and is, together with the buildings connected with it, constructed entirely of concrete. The base is on a small rocky mound rising out of a plain of sand only slightly above sea-level. The concrete was made of this sand and of stones from ruins in the vicinity, thus saving the very expensive carriage of material. The foundation block is 39 feet 4½ inches square, and altogether 13 feet 1½ inch high. The tower has an internal diameter of 5 feet 11 inches, an outside diameter of 10 feet 6 inches at top and 27 feet 10½ inches at bottom, the platform being 137 feet 4 inches above the foundation block, the height over lantern above foundation 151 feet 6 inches, and the centre line of the light being 181 feet 9 inches above high-water level.

The concrete is formed of two volumes of stone, broken to pass through a $2\frac{1}{3}$-inch ring, to one volume of mortar; but the mortar for the base consisted of 506 lbs. of Teil hydraulic lime, and that for the tower of 590 lbs. of Portland cement, per cubic yard of sand. Large stones, to the extent of a quarter of the volume of concrete, were also buried in the foundation block. The tower was built by means of internal iron moulds, to which were secured the outer cylindrical mould of planks held together by iron bands, the size of the outer ring being reduced as the work rose, and the steps thus formed on the outside being filled in afterwards with mortar formed of 927 lbs. of cement per yard of sand. A helical groove was at the same time left on the inside of the tower, into which the steps of a circular staircase were afterwards fixed. These steps were also of concrete, consisting of two volumes of brick, broken to pass through a $\frac{3}{4}$-inch ring, to one volume of the mortar used on the outside of the tower. The necessary buildings for the staff, viz., one native and two European attendants, were grouped at the back of the lighthouse tower; and two tanks for rain-water were provided, this being the only available supply of fresh water.

The pressure of the foundation on the soil was calculated at 27 lbs. per square inch, and the maximum pressure on the concrete of the tower at 64 lbs. per square inch, allowing for wind-pressure of $51\frac{1}{4}$ lbs. per square foot, and 131 lbs. per cubic foot for the weight of the concrete. During construction the base settled, quite evenly, to an extent of $5\frac{1}{2}$ inches. Tests of the mortars gave the following tensile strengths:—

After Days	7	14	30
For the base, in air . . . . . lbs. per sq. in.	71·1	93·8	119·4
" " , immersed in water . . " "	..	99·5	186·3
For the tower, in air . . . . " "	162·2	162·8	165·7
" " , immersed in water. . " "	..	131·5 (?)	255·9
For the steps, &c., in air . . . . . . " "	220·4	233·2	224·7
" " , immersed in water " "	..	243·2	384·7

7·87-inch cubes of the lime concrete crushed at the following pressures per square inch: after thirty-six hours, 23·1; after eighty-four hours, 42·1; after 144 hours, 45·5; and after fifteen days, 100·3, while similar cubes of the cement concrete for the tower, after twenty hours, crushed at 119·4 lbs. per square inch, and, after eighty-four hours, at something above 227·5 lbs., the apparatus being incapable of a higher pressure. The actual weight of the lime concrete was found to be 133·3 lbs. per cubic foot, and of the cement concrete for the tower 142·3 lbs.; but the strength of the concrete was shown to be sufficient for the extra weight above the estimate. The total cost of the lighthouse complete was £3,440, of which £2,560 was for the tower and

buildings. The light is a white one with a double flash at intervals of ten seconds, and visible at a distance of 30 miles. The tower has been most successfully constructed, the work being authorized in August 1894, and completed in the summer of 1895.

The Paper is illustrated by a sheet of plans of the tower and three wood-cuts.

R. B. M.

The Reconstruction of Forts at Cherbourg. G. RICHOU.

(Le Génie Civil, 22 May, 1897, p. 49.)

The forts on the breakwater at Cherbourg have lately been reconstructed and strengthened, and the new work has been executed in concrete. The chief point of interest in this work is the very small space which was available for the plant and storage of materials, while the output of concrete necessary to complete the work in the specified time was about 78 cubic yards per hour. Both lime and cement concrete were used, the proportions being for the former 1 cubic yard of broken stone and shingle to 0·78 cubic yard of mortar consisting of $\frac{1}{3}$ hydraulic lime and $\frac{2}{3}$ sand; and for the latter 1 cubic yard of broken stone and shingle to 660 lbs. of cement, 0·3 cubic yard of sand, and 20 gallons of water. The materials, when landed from barges, were lifted at once to a sufficient height to allow them to pass through the concrete machines by gravity. The mortar was first mixed dry, then with the water, then the broken stone and shingle were added, and the whole mixed together by falling into the wagons conveying it to the required position.

The wagons of concrete were hauled up an incline to a travelling gantry, from which the concrete was tipped behind the concrete frames. This gantry was supported at the two ends while the intermediate piers and arches of the forts were being filled in; it was then supported at the inner end and at the centre to allow the outer wall to be made under the overhanging end. In this manner, the work was carried out with very little shifting of the concrete mixing plant or of the permanent way, temporary openings being left in the walls to allow the materials to be brought in.

There are two illustrations showing the manner in which the yard and gantry were arranged.

R. B. M.

The Purification and Ventilation of the Subsoil.

HERM. KOSCHMIEDER.

(Gesundheits-Ingenieur, 31 July, 1897, p. 229.)

The dangers caused to health by various impurities in the subsoil are enumerated, and certain recent outbreaks of typhoid fever and cholera due to this cause are recalled. The Author states that modern sewerage works and improvements effected in paving and in the scavenging of towns, have greatly improved the condition of the underlying soil, and in many cases have undoubtedly diminished the death-rate from typhoid fever; thus Dr. Max von Pettenkofer was able to write in 1891, as respects the sanitary state of Munich, that, owing to the gradual purification of the subsoil, the deaths from typhoid fever had in eleven years been reduced from an annual average of from 150 to 330 per 100,000, down to an average of 10 to 12 per 100,000 in the twelve months. By reference to a diagram the Author shows the plan he has devised for preventing the entry into the cellars of the vitiated air from the subsoil. This is effected by constructing a hollow wall so as to form a dry area round the basement. This hollow space is used to ventilate the soil surrounding the building, and the air which penetrates into it from the outside is exhausted by a vertical pipe with branches leading into the front and back dry areas, and carried up in the centre of the house above the roof. It is explained that the warmth of this pipe will cause an updraught which will constantly tend to remove the foul air from the dry area and prevent its access through the porous walls of the basement into the house as at present. Among the advantages claimed for this system are the provision of means for the healthy ventilation of the subsoil, if all the houses in a street are thus constructed; the prevention of gas explosions caused by the escape of gas from broken street mains into cellars, and the ready means afforded of testing the soundness or otherwise of the gas-pipes under the roadways.

G. R. R.

Separation Systems. METZGER.

(Gesundheits-Ingenieur, 15 August, 1897, p. 241.)

Reference is made to a work, published by the Author in 1896, giving an account of a system of sewerage designed and carried out by him in Bromberg and in Insterburg, in which separate provision is made for the conveyance of the rain-water and of the sewage by the use of concrete sewers with double channels. The separation of the sewage proper from the rainfall is very little practised in Germany, but it is shown from the opinions of those

who have studied this question that this plan has much to recommend it. One of the chief difficulties would seem to be that the small size of the drains used for sewage water alone might lead to silting up, and on this account it has been the practice, even in mixed systems of water-carriage, not to employ as sewers any pipes having a diameter of less than 25 centimetres to 30 centimetres (about 10 inches to 12 inches). A calculation is made of the actual amount of sewage water from a given area to be dealt with, and of the wetted section of egg-shaped sewer needed for this volume of water. The rainfall to be discharged is assumed to be seventy-five times the volume of the sewage-water, and the amount of water used for flushing purposes is set down as equal to the total volume of the sewage proper. In Breslau the water for flushing was found to be 0·61 cubic metre annually for each lineal metre of sewers, or 1·25 cubic metre per head of the population. It is pointed out that, with a proper system of separation, it is possible and convenient to admit to the higher levels of the foul-water sewers a certain proportion of the rainfall, and an estimate follows of the water needed for flushing small sewers, taking a town of 50,000 inhabitants as an example. The form of double sewer advocated by the Author, which is made of concrete, is shown in a series of seven diagrams, for differences of diameter from 30 centimetres up to 90 centimetres, in the case of the circular pipe for rain-water placed above. Beneath in each diagram is a segment of egg-shaped sewer, giving the best self-cleansing section for the sewage-water, varying from 20 centimetres to 37 centimetres in depth by from 22·5 centimetres to 62·5 centimetres in width. The actual cost of carrying out this system of drainage per running metre is also given.

G. R. R.

The Construction of the Clichy Main Sewer. BECHMANN.

(Annales des Ponts et Chaussées, 1897, p. 267.)

The construction of this sewer became necessary owing to the insufficiency of the drainage system of this portion of Paris. The work was divided into two sections; the first, 1,917½ yards long and lying close to the surface of the streets, was completed in October 1896; the other, 2,816½ yards long, is much further from the surface, and was still under construction when this Paper was written. The mode of construction in both cases was by means of a metal shield, pushed forward by hydraulic pressure, the masonry being built on metal centering erected to support the soil as the shield moved forward. In the first section, however, the shield only extended over the elliptic upper portion of the tunnel, the invert being put in after the arch was completed, while in the second portion the shield formed a complete ring.

In the former case the shield rested at the bottom on cast-iron rollers bearing on timber baulks, and the masonry was built under a thin iron sheet which was not drawn, and here in some cases the surface of the street was only 27½ inches above the crown of the sewer. In both cases the forward travel of the jacks was the same as the distance between the metal centres, in the first section being 39⅜ inches and in the second 23⅝ inches. These jacks pressed against the iron centre behind them, the several centres being kept apart by iron beams in the line of thrust of the jacks, and a sufficient number of them—from thirty to thirty-eight—being left in at once, to allow of the brickwork and excavation being carried on uninterruptedly. The excavated material near the cutting edge of the shield was thrown into a conveyor which deposited it in small wagons in which it was conveyed to the spoil heap.

In the first section a steam locomotive was used for moving these wagons, but in the second the whole of the requisite power was electrical, including pumps, conveyor and ventilator. The sewer is elliptical in section, 19 feet 8 inches wide and 16 feet 5 inches high, with an average thickness of ring of 21⅝ inches, and footways on either side, leaving a sewage channel 13 feet 1½ inch wide by 6 feet 6¾ inches deep. The first section was let to Mr. Chagnaud, who had patented his method of construction, at £36 18*s.* per lineal yard, and the second section to Messrs. Fougerolle Brothers, who had also patented their method, at £27 19*s.* per yard forward, and under favourable circumstances the progress was from 6½ to 7½ yards per day.

The cast-iron siphon, under the Seine, circular in section, and connecting with this sewer, with an outside diameter of 8 feet 2½ inches, was constructed under air-pressure with a shield in a manner very similar to the Blackwall Tunnel. There are two sheets of details illustrating the shields and the method of construction.

R. B. M.

The Chicago Drainage Canal. F. W. SKINNER, M. Am. Soc. C.E.

(The Engineer, 6, 13 and 20 August, 1897, p. 125 *et seq.*)

This canal[1] was designed to free Lake Michigan from the sewage of Chicago by leading the Chicago river through it to the Desplaines river and thence to the Mississippi. The canal is 28 miles long, it has side slopes in earth of 2 to 1, with a bottom width of 202 feet.

The portion of the canal at the east end, adjacent to the Chicago river, was excavated by dredges of the jet or rotary types. Much of the excavation in the dry has been done by steam excavators

[1] Minutes of Proceedings Inst. C.E., vol. cxix. p. 433.

and removed by bridge or inclined conveyors. The former consisted of a bridge, at right-angles to the line of the canal, spanning the site for dumping the spoil, with an inclined plane leading to it, up which the spoil was hauled on to the bridge and dumped through its open floor. The bridge and incline were moved ahead on rails, as the steam excavator progressed. The inclined conveyor consisted of a triangular cantilever with one side parallel to the ground, running on wheels, and the apex reaching over to the centre of the spoil bank.

The rock excavation was done by working in trenches; the vertical sides of the canal were cut perfectly smooth by "channellers," which consisted of a traveller having a vertical steam cylinder of 10-inch stroke, to the piston of which a cutting-tool was directly connected, consisting of a row of diamond-pointed square bars clamped together, which cut a groove in the rock by percussion, and were replaced by narrower and longer bars as the slot was deepened. Transverse to the sides, rows of holes were drilled, charged with dynamite, and fired simultaneously by electricity. The resulting débris was removed by ropeways or giant revolving derricks.

A. W. B.

The Utilization of New York City Garbage.

(Scientific American, 14 August, 1897, p. 102.)

The household refuse of New York was formerly collected indiscriminately and carted to scows, which were emptied into the sea. This practice not only caused silting-up of the entrance channels, but it led also to unsightly deposits on the foreshore. In lieu of this wasteful method of disposal the refuse is now compulsorily sorted by the householders into three classes and placed in separate receptacles, which contain respectively the ashes, the garbage and the light refuse. The ashes, which comprise the residue from boiler-furnaces, household grates, &c., also include broken crockery, oyster shells and all material suitable for filling-in purposes. The ashes are separately dealt with under the new system by means of steam dumping-scows, and will be used for reclaiming swampy ground. The second class of refuse, consisting mainly of kitchen stuff, which amounts to about 800 tons daily, is carried in carts to seven different dumps, conveniently situated along the river front, and is loaded into scows for conveyance to the factory on Barren Island. These works are described in the present article by reference to diagrams and photographs of the machinery and plant. The light refuse which constitutes the third class, and which consists mainly of paper and rags, is at present being experimentally dealt with at the factory on the East River.

On reaching the works at Barren Island the garbage is raised by a conveyor and two large inclined elevators to the top of the factory for delivery into bins, from whence it is discharged, by a series of large swivel-pipes, into digestors, forty-eight in number, ranged in rows of four down the centre of the building. These digestors are cylindrical tanks of plate steel, each 5 feet 6 inches in diameter and 18 feet high. In these the garbage is cooked for a period of from eight to ten hours under steam at 50 lbs. pressure, by means of which it is thoroughly disintegrated and reduced to a pulp-like consistency. The matter is then dropped into a set of twelve storage tanks, from whence it passes, by curved delivery-pipes, on to press platens, carried on small trolleys. On the platens are placed the moulds for the hydraulic presses, and the liquid matter is folded in burlap and stacked in sets until the pile reaches about 4 feet in height. In the presses, which work very slowly, the cooked material is subjected to a pressure of 250 tons, and brought down to less than half of its former bulk. The cakes are then removed from the press-frames and dried in cylindrical steam driers, in which the substance is at the same time pulverized, and it is subsequently sifted for sale to manure manufacturers as a filler. The grease and water extracted by the presses pass into a series of ten settling tanks, in which the grease rises to the surface and is skimmed off for sale to soap and candle-makers; the water, which contains about 14 per cent. of dissolved ammonia and 1½ per cent. of potash, is pumped into an evaporator in which these substances are recovered for admixture with the solid refuse from the presses. In addition to the plant already erected, the Company is about to put up a plant to work the refuse-screenings, which will be cremated in retorts and will yield a certain amount of sulphate of ammonia.

G. R. R.

Amount of Formic Aldehyde evolved by Means of Lamps or by the Use of Formalin for Disinfection Purposes.

PAUL STRÜVER.

(Zeitschrift für Hygiene, vol. xxv. part 2, p. 357.)

Having been instructed to make some trials of the efficacy of a lamp for the evolution of formic aldehyde, the Author carried out a series of experiments to test the amount of this gas obtained by the various forms of apparatus which have been proposed for the purpose, and he also compared the disinfecting power of these vapours with the action of formalin used as a spray and in other ways. In the first instance he ascertained the actual percentage of formic aldehyde obtained from a given volume of methyl alcohol, and he found that not more than 2·5 per cent. of formic aldehyde was produced by the lamp in question, which depended

for its action upon the imperfect combustion of methyl alcohol over a platinum gauze. In a second experiment the vapours evolved contained 2·8 per cent. of this gas. He then made use of an apparatus similar to that employed by Tollens for his experiments, and in the course of a series of trials he never obtained more than 9·28 per cent. of formic aldehyde, as compared with the 31 per cent. claimed to have been obtained by that experimenter. A further series of tests were carried out with a lamp of the kind employed by Dieudonné, and with this lamp the results were almost identical with those in the previous series of trials. As the mean of fourteen sets of experiments, the average evolution of formic aldehyde gas was about 8 per cent. Having in the meanwhile heard of Krause's experiments, in which a slight modification in the lamp was introduced, he carried out some comparative tests which fully accord with Krause's results. In the same way he confirmed the conclusions arrived at by Pfuhl.[1] The apparatus employed by the latter led to the evolution of formic aldehyde equivalent to about 9 per cent. of the methyl alcohol employed.

In order to test the percentage of formic aldehyde gas present in a given volume of air, and the disinfecting values of various mixtures of air and gas, the Author made use of an air-tight iron cupboard with a total contents of 880 litres. Into this he introduced the vapours evolved in different ways, and from time to time withdrew samples of the mixtures of air and formic aldehyde for analysis. He also evaporated and sprayed formalin, and made a series of experiments upon bacilli with holzin and formochloral, the results of which are given in tables. He likewise tested the bactericide properties of these compounds when mixed with air under various conditions. He states that, for the disinfection of small spaces, such, for instance, as the contents of cupboards, the best and safest method is to employ the formalin in the shape of spray. In order to be certain that complete disinfection has been attained in the case of large apartments, not less than 2·5 grams of formic aldehyde must be reckoned for each cubic metre in the case of spore-forming bacilli, or 1·6 gram in the case of non-spore-forming bacilli. When using holzin for spraying about 7 cubic centimetres suffice for each cubic metre of the space to be disinfected.

G. R. R.

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[1] Minutes of Proceedings Inst. C.E., vol. cxxvi. p 440.

Determination of the Density of Smoke from its Colour.

(Zeitschrift des Vereines deutscher Ingenieure, 31 July, 1897, p. 885 *et seq.*)

Up to the present there appears to have been only one method of determining the amount of unconsumed carbon, etc., passing into the atmosphere through factory and other chimneys; namely, that of Minary which involves the necessity of laboratory appliances, and is somewhat tedious. The Author describes an easy and yet equally accurate method by colour, and which requires very simple apparatus.

E. C. S.

Hydraulic Laboratory, Cornell University, U.S.

E. A. FUERTES. M. Am. Soc. C.E.

(Proceedings of the American Society of Civil Engineers, August, 1897, p. 133.)

This laboratory is located at the Cornell University on the south shore of a stream which has a water-shed of 117 square miles, its minimum flow being 12 cubic feet per second, and maximum flow nearly 5,000 cubic feet per second. A dam across the stream can be made to store 50,000,000 gallons of water. At the south of the dam a canal has been blasted out of the rock, 16 feet wide and 10 feet deep, and it extends 500 feet down stream. Sluice-doors regulate the entrance of water to the canal, baffle-plates and other contrivances controlling the conditions of its entry. It is provided with weirs which can be placed under identical conditions, and the water-tight canal can be used as a measuring basin. The height of the water in the canal can be read at short intervals by means of micrometers.

The canal can discharge into a 6-foot diameter steel-pipe. Also, by the side of the canal and parallel to it, a steel-pipe, 3 feet in diameter, can deliver water either into the 6-foot pipe, the canal, or directly into a building, under 80 feet head, to supply water-pumps, and dynamos for lighting and power-supply purposes.

Half way down the 6-foot pipe, a stand-pipe, under cover, enables experiments to be made on all kinds of orifices and nozzles, &c., up to 4 inches diameter, and under constant and variable heads; also special castings and reducers can be attached to the steel-pipe to enable experiments to be made on pipes and valves from 6 inches to 4 feet diameter. Upon the walls of the canal itself, two rails support a truck, provided with a small electric motor, that can be adjusted to run the truck at suitable velocities for rating current-meters, &c.

A. W. B.

Pressures resulting from Changes of Velocity of Water in Pipes. J. P. Frizell, M. Am. Soc. C.E.

(Proceedings of the American Society of Civil Engineers, August, 1897, p. 414.)

The Author considers the velocity of propagation of a pulsation in a pipe occasioned by the closing of a valve. By taking into consideration the compression of the water and the distension of the pipe caused by the increase of pressure, he arrives at the following value for the velocity of pulsation V in feet per second:—

$$V = \frac{L}{t} = \sqrt{144 \frac{g}{624} \cdot \frac{m M T}{2 r m + M T}}.$$

L is the length in feet of pipe affected by the pulsation, m and M are the moduli of elasticity of water and the metal of the pipe respectively in pounds per square inch, T the thickness of the pipe in inches, and r the radius of the pipe in feet. Also for the increase of pressure f in pounds per square inch above the static pressure:—

$$f = \frac{v}{L} \cdot \frac{M T m}{2 r m + M T},$$

where v is the velocity of the water in the pipe in feet per second.

A. W. B.

The Estimation of Oxygen in Coal-Gas.

(Journal of Gas Lighting, 17 August, 1897, p. 370.)

The introduction of continuous revivification of oxide of iron in purifiers, by the addition to the entering gas of a small proportion of air, has suggested a rapid and exact method of estimating small amounts of oxygen in coal-gas. This has been perfected by Dr. Otto Pfeiffer of Magdeburg. He employs an alkaline solution of pyrogallol, which turns yellowish-brown by the absorption of oxygen. About 100 cubic centimetres of the gas are collected in a burette, and while the upper stopcock remains closed, water is withdrawn from the lower stopcock until it only occupies the capillary. About 0·2 gram of pyrogallol is admitted and agitated with the air. If as little as 0·25 per cent. of air is present in the gas the liquid becomes coloured, owing to the formation of galloflavin. This is the qualitative test. The quantitative test depends upon the measurement of the depth of the yellowish-brown tint by comparison with solutions of caramel of different strengths, which have been carefully prepared and tabulated.

A. P. H.

Carburetted Water-Gas.

(Engineering, 23 July, 1897.)

The Saltley Gas Works have recently been equipped with plant for the manufacture of carburetted water-gas. The plant consists of a generator, a superheater and fixing-chamber, combined with an oil-atomiser, and an ordinary washer, scrubber, &c. The generator is filled with coke, and air is forced through until the generator, superheater, and fixing-chamber are raised to a high temperature. From the latter the products of combustion escape to the air. The "run" proper is then commenced, and steam is blown under the fire-bars of the generator. This produces ordinary water-gas, consisting of carbonic oxide and hydrogen. Passing through the superheater, which is filled with chequer brickwork, the water-gas meets a spray of petroleum which is at once vaporised. The two are carried up into the fixing-chamber, which is full of chequer brickwork at a high temperature, where they form a thoroughly permanent and high candle-power gas. The subsequent treatment is similar to that of coal-gas. After the run has continued a certain time, it is stopped, and the process of blowing up the heat is repeated.

A. P. H.

A Comparison of Fuel-Gas Processes. F. L. Slocum.

(Journal of Gas Lighting, 17 August, 1897, p. 379. Paper read before the New York Society of Chemical Industry.)

Methods of producing fuel-gas can be divided into :—

(1) Coal-gas. The yield from 1 ton (2,000 lbs.) of coal is 10,000 cubic feet of gas of a calorific value of about 600 B.T.U. per cubic foot, 1,400 lbs. of coke, 100 lbs. of tar, 5 lbs. of ammonia, and 0·75 lb. of cyanogen.

(2) Water-gas. The yield of 1 ton of coal (2,000 lbs.) is about 51,250 cubic feet of gas of an average calorific value of 363 B.T.U. per cubic foot, 8·03 lbs. of ammonia as sulphate, and a considerable amount of tar. The ideal gas machine of this class would convert all volatile matter into coal-gas, and all carbon into water-gas.

(3) Producer-gas. The Siemens non-regenerative gas producer yields gas of a calorific value of 878 B.T.U. per cubic foot, and the Mond producer, which admits of the preheating of air on the regenerative system, and the recovery of ammonium sulphate, yields per ton (2,000 lbs.) of coal, 160,000 cubic feet of gas of a calorific value of 156·9 B.T.U. per cubic foot, and 100 lbs. of ammonium sulphate.

The percentage of the total heat of the original coal from which the gas is made, which is available in the gaseons fuel, is as follows:—Coal-gas, 20 per cent., water-gas, 61·63 per cent., Siemens gas, 60 to 65 per cent., Mond gas, 80 per cent.

A. P. H.

Testing Commercial Liquefied Ammonia.

Drs. H. Bunte and P. Eitner.

(Journal für Gasbeleuchtung, 1897, p. 174.)

The greater portion of the ammonia obtained from gas liquor, for ice manufacture, has for some years been sold as liquefied ammoniacal gas. In consequence of incorrect testing it has been thought to contain a considerable quantity of water, but this is not generally the case, if the ammoniacal gas is carefully dried before compression. It is, however, desirable to determine the quantity of water present, and the Authors have devised a simple and reliable means for doing this.

About 1 oz. of liquefied ammonia is taken into a pipette provided with a stopcock at each end. To separate the dissolved impurities from the ammonia it is allowed to pass slowly from the pipette, which for this purpose is placed upright in a cylinder, the upper end being connected with three drying tubes, filled with solid caustic potash and accurately weighed, the issuing stream of gas is allowed to discharge under mercury, the stream being regulated by the upper stopcock. With the escape of the ammonia the pipette becomes considerably cooled, and is covered with a thick crust of ice from the moisture in the atmosphere; this disappears in from four to six hours after the operation is completed. Some drops of a brown fluid remain in the pipette, consisting partly of water saturated with ammonia and partly of an alcoholic organic substance and carburetted hydrogen, coloured with traces of tarry constituents. When the pipette is at the same temperature as the surrounding air it is placed horizontally in an air-bath, which is gradually heated to a temperature of 158° F. to 176° F., and is connected with a drying apparatus, filled with solid caustic potash, a stream of dried air being allowed to pass through the apparatus. By this means the volatile organic compounds and the water pass into the first potash tube. A trace of a brown organic substance remains in the pipette, which is insoluble in alcohol or ether, but soluble in nitric acid and liquid ammonia; the quantity of these substances is generally very small (0·08 per cent.). The weight taken up by the potash tubes and that of the pipette represent the impurities contained in the liquefied ammonia.

Example.

Weight of the empty pipette	2·186 ozs.
Ammonia employed	0·9436 oz.
Remaining in the pipette	0·376 gr.
Increased weight of the potash tubes	1·841 „

The liquefied ammonia consequently contains:—

	Per cent.
High-boiling organic substances	0·08
Volatile alcoholic matter and water	0·41
Total impurity in the liquefied ammonia	0·49

C. G.

The Use of Beech Wood for Railway Sleepers.

(Annalen für Gewerbe und Bauwesen, 1 August, 1897, p. 50.)

Attention is directed to the large area in Germany which is covered by forests of beech, and to the great importance of utilizing this timber for industrial purposes, instead of employing it as at present, mainly for fuel. The chief German consumption of foreign timber is for railway purposes, not less than £650,000 being expended annually for sleepers alone by the Prussian State Railways. In the year 1895, out of 4,495,973 sleepers to be supplied for German railways, only 79,670, or 1·75 per cent., were of beech wood. This was due to the fact that previous trials of this timber were not considered favourable, but Mr. A. Schneidt, railway-traffic manager of Strassburg, states that when properly treated, beech is capable of giving extremely satisfactory results, and is even more durable than oak, which has hitherto been regarded as the most lasting of all materials for sleepers. Attention is called to the results obtained by the French Eastern Railway Company, who have used beech sleepers for many years. The timber is impregnated with tar-oil containing carbolic acid. During twenty-one years' experiences the following proportions of the sleepers were renewed—of untreated oak sleepers 52 per cent., creasoted oak 26·8 per cent., and of creasoted beech 6·4 per cent., from which it follows that the beech sleepers were undoubtedly more durable than those of oak. This, as Mr. Schneidt points out, is readily explained by the large relative percentage of tar-oil taken up by the beech wood, which counteracts all tendency to decay. At the International Railway Congress in London in 1895, it was asserted that beech wood was not only an excellent material for sleepers, but that it was likewise the cheapest.

G. R. R.

On the Wear of Steel Rails. G. Oliva.

(Report of the Chief Engineer to the Italian Mediterranean Railways, 1897.[1])

Two types of rails are referred to in this Report, viz.:—(1) Vignoles or flange rail, at 72½ lbs. per lineal yard (Appendix I.). (2) Double-headed rail, at 80½ lbs. per lineal yard (Appendix II.). The maximum reduction of thickness of the head allowed before renewal is: type 1, 0·63 inch; type 2, 0·79 inch.

Fracture of Rails.—Full particulars are given of the fractures of rails from July 1, 1885, to December 31, 1895, on various lines

[1] The original is in the Library Inst. C.E.

of the Company's system presenting the greatest variety of conditions of wear. On certain sections the number of fractures is very high; *e.g.*, on the San Giuseppe and Bra line, on gradients steeper than 1 in 50 and on curves of less than 25 chains radius, the proportion per annum was 17·48 per mile; on the San Giuseppe and Savona line 14·81 per mile, and so on.

The fractures occur either longitudinally or transversely. The former are generally fissures in the upper portion of the rail-head, and are due probably to defects in the metal. Any internal discontinuity of strength subjects the rail to disintegration under the impact of successive loads, combined with the slipping and racing of wheels on steep inclines and the use of sand under the driving-wheels.

Transverse fractures are generally of much less frequent occurrence. Most of the recorded exceptions to this rule have been on the line from Bussoleno to Beaulard, which was one of the earliest sections laid with steel rails. In general, the transverse fractures begin to outnumber the longitudinal fractures when the rail is worn to nearly its fullest allowable extent (*cf.* examples quoted, Table II.).

Gradual Wear of Rails.—Apart from the mechanical action of work performed by the passage of the trains the principal causes of wear are the chemical action of the gases developed in imperfectly ventilated tunnels, and the corrosive action of the salt air on coast lines.

With regard to the mechanical element of wear, reference may be made to Appendix III., where the wear for twelve months is shown, as well as that caused by the passage of 1,000 trains. Statistics are also given in Table III. of the wear on various gradients and curves. The diagram shows clearly the effect of long tunnels, of stations, of the neighbourhood of signals, &c., on the life of the rails. Apart from the abrasion of the rail-head, deterioration is evident on all the parts of the permanent way at their surfaces of contact.

Chemical Action in Tunnels.—This action, due to the mixture of acid vapours and products of combustion from the locomotives, is most observable on the underside of the flange of the rails, where a species of permanent layer of corrosive liquid is formed between the surface of the rails and that of the chairs.

Various instances of this are given in detail. On one of the rails (Vignoles type) on the descending line in the long Ronco tunnel (Appendixes IV. and V.) the corrosion of the flange in two-and-a-half years amounted, in various places, to 0·086 inch. On the ascending line in the same tunnel the maximum flange corrosion after three-and-a-half years was, in some cases, as much as 0·22 inch to 0·26 inch; and after four years' wear 0·28 inch to 0·3 inch. The corrosion had honeycombed the entire undersurface of the flange. Other examples are illustrated—from the Frejus tunnel, on the Turin and Modane line; from the Sella tunnel, on the San Giuseppe and Savona line; and from the Belbo

tunnel, between San Giuseppe and Bra. In the Laveno tunnel, between Novaro and Pino, where transverse fractures necessitated the removal of various rail-lengths, a most extraordinary degree of corrosion was noted, amounting to 0·39 inch on the underside of the flange, while the abrasion of the head amounted (in the worst case) to 0·49 inch, the rails having been laid eleven-and-a-half years.

Action of Sea-Air on Coast-Lines.—This source of corrosion has been chiefly observed on the Ligurian Riviera, where the line is not merely exposed to the salt air but is frequently subject to drifts of spray from the waves. In such cases the rail frequently reaches its limit of safety long before the normal wear has been attained. For instance, on the Celle and Cogoleto section of the line from Genoa to Ventimiglia, the Vignoles rails, after fifteen years' service, showed a reduction of only 0·118 inch to 0·158 inch on the head, but were much corroded in the flange, frequently to the extent of 0·158 inch to 0·236 inch; while the width of the flange was correspondingly reduced by 0·39 inch to 0·6 inch, and in some cases even 0·79 inch.

Permanent Elongation and Deflection of Rails.—In addition to abrasion and corrosion, other destructive agencies may be noted.

On the Mont Cenis approach line, between Meana and Chiamonte, on a gradient of 1 in 34½, laid with Vignoles rails, it was found in several cases that the original clearance between the rail ends had entirely disappeared, and that one or both of the rails had extended longitudinally, pressing together, causing the head to bulge out—in one case to the extent of 0·39 inch—correspondingly decreasing in height and tightening the gauge by fully $\frac{3}{16}$ inch. Between the points of support the rails were also conspicuously deflected, so that the number of supports could be counted by the successive curvatures or undulations of the rail. This was evidently due to the defective quality of the steel.

Experimental and Actual Methods Adopted for Diminishing the Wear or Deterioration of Rails.—During the past three years a harder steel has generally been specified than was formerly adopted. The old specification was, tensile strength 35 tons per square inch (sometimes even less) with minimum elongation 18 per cent. to 20 per cent. Except in special cases the normal tensile strength now required is from 41 tons to 44½ tons per square inch, with minimum elongation 14 per cent. Experiments were also made with a view to the adoption of a rail not greatly exceeding in weight the old type, but with larger bearing surfaces. The type now adopted is shown in Appendix VIII. The width of the head is increased from 2·36 inches to 2·83 inches, and the weight is 90¾ lbs. per lineal yard. The area of abrasion allowable is 2·23 square inches, as against 0·72 inch in the old type.

Since the adoption of the new section, no instance of elongation or undue deflection has been noted, and the extent of abrasion has been considerably diminished. The new rails laid in the Ronco tunnel, for instance, in October, 1894, were examined in February,

1897, *i.e.*, after two years and four months, and the reduction of the head amounted to only 0·118 inch.

The results of the methods adopted for securing a diminution of chemical or corrosive action have not yet been demonstrated on a sufficiently reliable basis.

On the Celle and Cogoleto section of the Genoa and Ventimiglia line, some of the rails relaid in 1891 were coated with tar and with other ironwork varnishes. When examined in 1896 the results varied in different parts of the rail. The friction of the portions bedded in the ballast or in contact with the chairs and fastenings had naturally worn away the coating; but though rust was slightly formed, very little trace of corrosive action was observable. In the exposed portions the protective coating stood remarkably well.

Concurrently with this, a similar experiment was being made in the Frejus tunnel, and the rails were examined after an average wear of three years and eight months. The Bessemer varnish was found to have been the most effective coating, next to this being tar, two coats. Although the period was too short for the establishment of conclusive data, it appears to be distinctly proved that the small outlay for a protective coating is amply justified by the additional life and soundness of the rails.

In conclusion, reference is made to the system of inspection and maintenance of the permanent way on the company's lines.

The Paper is accompanied by a series of Tables forming the Appendixes referred to.

P. W. B.

Deterioration by Fatigue in Steel Rails.

THOMAS ANDREWS, M. Inst. C.E.

(Engineering, 13 July, 1897.)

A Bessemer steel rail, originally 80 lbs. per yard, which had been in wear on one of the principal English railways for twenty-three years, was found to have lost 3 lbs. per yard in weight, or at a rate of 0·13 lb. per yard per annum. The face had worn down $\frac{1}{8}$ inch. On the wearing surface at the end of the rail were found numerous fine longitudinal cracks, but the middle portion was in fairly good order. Microscopic examination of a section of the rail showed the normal carbide of iron areas to be properly and evenly distributed, though there were numerous micro-sulphur flaws. A 10-inch test-piece cut from the head of the rail gave:— tensile strength, 34·79 tons per square inch; elongation, 22 per cent.; and reduction of area, 48·4 per cent. Chemical analysis showed carbon and manganese to be rather low (0·38 per cent. and 0·446 per cent. respectively). Sulphur high (0·089 per cent.)

and phosphorus abnormal and excessive (0·13 per cent.). The investigation points to the lurking danger from micro-sulphur flaws, and the Author suggests methods of inducing rail-makers to minimise harmful impurities.

A. P. H.

An Investigation of the Physical Properties of Compressed Iron Tires. F. GROVER, Assoc. M. Inst. C.E.

(The Engineer, 3 September, 1897, p. 217.)

In connection with experiments on fixing by pressure, iron tires, made larger than the wheels they are intended to fit—*e.g.*, in case of a 3-foot 6-inch wheel, the tire is 1½ inch greater diameter—and compressed on to the wheel cold, by eighteen hydraulic rams fixed round it, the Author arrived at the following conclusions:—

(1) High compressive strains induced in iron bars raise the elastic limit in tension.

(2) The tension modulus of elasticity is slightly lowered.

(3) The iron gives a crystalline fracture after the application of the pressure, but annealing restores it to the fibrous state.

A. W. B.

Dynamometer for Signal and Switch Reversing Levers.

C. SCHALTENBRAND.

(Organ für die Fortschritte des Eisenbahnwesens, 1897, p. 143.)

The Author, after describing the defects in the ordinary method of determining the amount of force required to work reversing levers as at present constructed, describes a recent invention by which such defects are remedied, the work simplified and the distance through which the lever-handle moves reduced to a minimum.

This arrangement consists of three principal parts; (*a*) the lever handle; (*b*) a curved support for the bearings; (*c*) registering spring gauge at each end of the lever-handle.

The dynamometer is inserted by means of connections of various forms adapted to the particular construction of the different levers in use. When attached to the lever to be tested, the handle must be worked steadily in both directions and then the sliding indicators will register correctly the force exerted at each operation.

The Author describes at length both the method of working and the separate parts and appliances connected with his system; the Paper is also furnished with six illustrations.

W. A. B.

Special Train-Service for the Chantilly Races and Bouré's Interlocking System. M. ZIMMERMAN.

(Revue Générale des Chemins de Fer, July, 1897, p. 3.)

The Northern Railway of France has every year to provide for an abnormal influx of passengers during the race-week at Chantilly. Between the hours of 11 and 1 o'clock more than 20,000 have to be trained from Paris to Chantilly as rapidly as possible.

The excellent arrangements at Paris render this possible, but until this year the station accommodation at Chantilly was very defective. Last February a commencement was made, and a station designed especially for the race traffic and completed within three months. It comprises ten lines of rails with six separate platforms, 656 feet long, 20 feet wide, approached from a cross platform at the north end 40 feet in width. The sidings are so arranged that it is possible in an incredibly short time, and at regular intervals, to despatch trains according to the formula $n + (n - 1) + n - 2 \ . \ . \ . \ . + 1 = n\left(\frac{n + 1}{2}\right)$; in this case $n = 10$, and the number of trains fifty-five.

As the station is used only for a few days once every year, an elaborate system of interlocking points and signals would have been a useless expense; at the same time the safety of the passenger traffic had to be provided for, and this has been done by the simple and inexpensive system invented by Mr. Bouré. The Author describes most minutely every detail of the above system and the way it is worked at Chantilly. He states that on the 30th May, 1897, twenty-three special trains, containing 25,000 passengers, were despatched from Chantilly in one hour and thirty seconds. The Paper is illustrated by numerous diagrams and Tables, and a most complete set of plans and drawings of every detail.

W. A. B.

Electrical Lighting for Passenger Carriages on Railways. Dr. MAX BÜTTNER.

(Verhandlungen des Vereins für Eisenbahnkunde, 1897, p. 45.)

In this Paper, the Author, after tracing the gradual development of the accumulator introduced in 1879 by Gaston Planté, proceeds to describe the various methods in which electricity has been employed for the purpose of lighting passenger-carriages on railways in Sweden, Norway, Russia, Germany, Switzerland and Austro-Hungary. A general outline of each of the above systems is given, and from the statistics supplied it appears that the use of electricity for the purpose is decidedly on the increase. The

hindrance to its more rapid extension by the more important railway companies the Author attributes to the immense cost of converting existing plant, &c.

Diagrams of the relative cost of gas, acetylene, a mixture of these two, and electricity are given, which show results decidedly favourable to electric light as regards both cost and cleanliness.

W. A. B.

Electric-Power Plant on the Brooklyn Bridge.

(Electrical World, 1897, vol. xxix., p. 119.)

Since its first erection the traffic across the Brooklyn Suspension Bridge has increased so much that the trustees have continually been obliged to give additional facilities for transit, especially upon the railway, and important new works with this end in view were begun two years ago, including the enlargement of terminal stations and the introduction of electric power for switching over the trains from incoming to outgoing tracks.

So far as the railway is concerned, the capacity has been to all intents and purposes doubled by the provision of two more tracks, making four altogether. The additional tracks are not, however, spaced the usual distance apart from those previously laid; as a matter of fact they overlap the latter, the respective rails being only a few inches from one another.

The headway of trains, however, may be greatly increased, since two cables can be run for each pair of tracks, used alternately by succeeding trains. Moreover, it is obvious that the additional cables will prevent total breakdown of the service due to rupture of any one. The importance of the traffic is clear when it is remembered that last year alone over 44 million passengers were carried across the bridge.

Considerable time was unavoidably lost at the termini in shunting the trains across by means of steam locomotives, and it was, as stated, determined to substitute electric motor-cars for the purpose, owing to the great rapidity and ease with which they can be manipulated. The necessary line conductors for a third-rail system, with feeders, &c., also suitable rolling stock was duly provided, and the electric switching begun last November; but a week or two later an accident happened to the power-house of the Brooklyn City Railway (which was supplying current), and hence the bridge authorities decided at once to put in their own plant, making use of outside supply only in case of further accident.

The generating plant consists of two direct-coupled units—inverted vertical non-condensing high-pressure steam-engines coupled to 400-kilowatt Walker dynamos, each with ten poles, and designed to give 800 amperes at 500 volts and 100 revolutions per minute. Two Babcock-Wilcox boilers working at 200 lbs. pressure

supply the necessary steam; the engine cylinders are 30½ inches diameter with a stroke of 36 inches; Porter-Allen independent flat-balanced valves are employed for steam-distribution.

Full details are given of the generator dynamos, which are, of course, over-compounded in the usual way for a 10-per cent. loss at full load; also of the switch gear and other station appliances. The generator magnet poles are of soft iron, laminated and cast into the yoke.

The distribution of current along the tracks is effected in three sections—the bridge proper and the two termini. A total length of nearly 4 miles of feeder cable is laid, these are erected on glass insulators set on wooden cross-arms; four negative feeders are also provided of equal section. The main feeders are connected to the third rail at intervals of about 350 feet, No. 0000 wire being used for the purpose. Section switches are provided, so that various parts of the line may be cut out of circuit when desired for repairs, &c. The third rail or positive conductor is fixed outside the track rails, not between them, as on the Liverpool Overhead Railway. It is a simple tee-rail bonded with No. 0000 bonds, and laid on vitrified clay insulators, one of which is set on every fifth tie. The insulators have a single petticoat, are shaped like a square pyramid, supported on an iron pin which passes through the tie, and at the top are fixed two jaws drawn together by a long bolt and nut and serving to grip the base of third rail.

The motor-cars resemble the ordinary cars used for the bridge service, measuring 45 feet over all in length, and weighing with motors about 30 tons. Each truck weighs 5 tons and has a wheel-base of 5 feet 6 inches. A 50-HP. motor is fitted to each axle of the trucks, there being four motors to each car. These machines weigh about 1¾ ton each. Their present duty is simply to shunt the trains across tracks at the termini, but should the cables fail at any time they are to be capable of drawing any of the regular trains, weighing about 120 tons, across the bridge at the cable speed of 11·3 miles per hour. One motor-car is allotted to each train, forming part of it, and carrying a share of the passengers, but is only called upon to propel the train at the termini; on the bridge proper the cables draw the trains.

Fourteen illustrations and reproductions from photographs accompany the article.

F. B. L.

An Electrically Operated Draw-Bridge. J. E. WOODBRIDGE.

(Electrical World, New York, vol. xxx., 1897, p. 7.)

Between the important centres of Duluth and Superior, at the head of Lake Superior, there has lately been built a large bridge crossing over the St. Louis river; and to give full scope to steamer traffic the centre span is made to swing on the centre. This span

is 500 feet in length, 58 feet wide and 88 feet high to the top of girders, weighing in all about 2,000 tons. It carries a double track for steam railroad trains between the truss members, and outside these, on the overhanging ends of floor beams, on each side, a track for electric trolley line, ordinary roadway for vehicles, and footpath for passengers.

For operating the swing, which takes only two minutes for traversing the full 90 degrees, there are installed two large electric motors of the G.E. 2,000 type; these have a speed reduction from armature shaft to bridge column of 1,500 to 1, through four intermediate spur gears and a worm gear. The final pinion and circular rack have teeth 10 inches wide with a 4-inch pitch.

As might be imagined with such a long span, the question of end support and lift requires as much care and consideration as the main swinging gear. The end lifts—which transfer the weight of the ends to the piers when the span is closed—consist of massive steel eccentrics having a throw of 4 inches; the clearance is 2 inches, so that a lift of 2 inches is given to the ends. This gives an estimated load of 50 tons per eccentric. The latter are operated by means of short stout eccentric rods pivoted at their lower ends to solid steel blocks or shoes, which are lowered upon masonry pedestals when the span is closed.

One G.E. 1,200 electric motor is placed at each end of the span to operate the eccentrics; they also release the latches and raise the rails on the steam track. This is necessary, because the rail ends are bevelled off to make joint. On the electric trolley tracks the rails are cut off square and do not therefore require raising. Two sets of spur gear and a worm gear are employed for each lifting motor.

Powerful magnetic strap brakes are fitted to all the motor mechanisms, and controlling apparatus in duplicate provided. The operating house which contains all this regulating gear is placed high up above the steam tracks at the centre of the span so that a full view of the road may be obtained both ways. Three views taken from photographs are appended.

F. B. L.

Modern Street Tramways.

(Zeitschrift für Transport-wesen und Strassenbau, 1897, p. 353.)

The Zeitschrift, in a series of three articles on the above subject, reviews the various descriptions of motors employed on the street-tramways on the Continent.

Under gas-motors mention is made of the Lührig system in use in Dessau; the Daimler in operation on the Würtemberg State lines, and Borsig's improved gas-engine. Each of these is described, and their performances, original cost and working expenses are given.

The electrical motors manufactured, and at present working on lines in Germany, are treated after the same manner, as well as the numerous systems of overhead and underground cables for the supply of electromotive power to the tram-engines. The three articles, in short, furnish a brief general account of the present class of motors in use on the continental tram-lines.

W. A. B.

The Hanover Electric Tramways. F. Ross.

(Elektrotechnische Zeitschrift, 1897, p. 178. 7 Figs.)

The Author says that he undertook to make a test of the working of the Hanover tramways all the more readily as they are partly worked by trolleys and partly by accumulators. At first the suburbs were worked by trolley-cars, but the municipal authorities refused to permit the use of overhead wires in the town. It was decided to try to charge accumulators in the cars from the overhead wires while in the suburbs, and allow them to work in the city with the charge so obtained, and the first test was made in September 1895. The length of trolley line is about 13·26 miles, and of this 10·97 miles has battery-car lines in connection with it. The batteries are charged over distances varying from 1·73 miles to 4·96 miles, and discharged over distances varying from 3·1 miles to 7·44 miles. In the power-station are four steam-engines, and four 150-kilowatt dynamos by Siemens and Halske. The overhead line has the bow collector, and the cars working on the mixed system are each fitted with 208 cells, having a total weight of 2·6 tons. The Author describes in detail the system of controlling switches used on the cars. Careful tests were made of the energy used both with empty and loaded cars, and it was found that when empty, about 780·64 watts per car-mile were used, and the car travelled at a speed of 9·9 miles per hour, and the loaded car took 780·64 watts per car-mile travelling at a speed of 8·1 miles per hour; curves showing the consumption of current are given, and the Author investigates a formula for the frictional resistance of the cars deduced from experiment. The average value on the Hanover line was about 10·56 lbs. per ton for a speed of 10·1 miles per hour, and as the resistance of the motor itself was about 8·14 lbs. per ton, the total resistance was 18·7 lbs. per ton. The Author considers that for Hanover and similar places the system adopted has very decided advantages, and obviates the necessity for using any system of collector groove in the crowded streets of a town.

E. R. D.

The Bersier System of Electric Tramway. A. BERSIER.

(Le Génie Civil, 19 June, 1897, p. 113.)

In this system one rail is of the ordinary girder type, while the groove of the other is about 4½ inches deep; and in this groove is laid an insulated cable. At distances of 16 feet 5 inches this cable is connected to contact-boxes against the groove, about 12 inches by 6 inches on the surface. The lids of these boxes are hinged on the side furthest from the rail, and are lifted by a "spoon" of peculiar construction, running in the rail groove and fixed at the end of the car, which also releases the lock preventing any unauthorised tampering with the live portions of the conductor. When lifted, the front of the lid makes contact with a bar running along the underside of the car, just inside the wheels, and from this bar the electric current is taken to the motors, returning by the rails. This bar is long enough to be always in contact with one box, and carries a "spoon" at each end. The box contains a switch, consisting of a sphere of copper, which, when the lid is sufficiently raised, rolls over and makes contact with a copper plate shaped to fit it. When the lid falls, being gently lowered again by the "spoon" at the back of the car, the sphere cuts the current between the cable and the front of the lid, but as the contact is at the same time broken between the lid and the car, the sparking is said to be very slight. The deep slot rail is made in two parts, is not difficult to roll, and weighs 115 lbs. per yard; the main portion is in lengths of 32 feet 10 inches, and that forming the side of the slot in lengths of 15 feet 9 inches—the distance between boxes. The insulated conductor, after being laid in the slot, is covered with sand and a thin strip of galvanized iron. The contact-boxes are of cast iron, and are fastened to oak cross sleepers to which the rails are also spiked. The cost of the electrical portion of the system is estimated by the inventor at £743 per mile, and successful experiments have been carried out on this system at Havre. The article is illustrated by a view of the car, and four diagrams.

R. B. M.

Electrical Cabs.

(Engineering, 20 August, 1897.)

The London Electrical Cab Company is at present putting on the streets of London a number of electrical cabs driven by accumulators. Out of a total weight of 30 cwt., including passengers, the accumulators weigh 14 cwt., which gives ample power for propulsion over the good roads and moderate gradients of London, without the normal rate of discharge being exceeded. The battery on each vehicle consists of a set of 40 E.P.S. cells,

with a capacity of 170 ampere hours when discharging at a rate of 30 amperes. It is supported on a tray slung by suspension links on springs, and is removed and replaced at the charging station by a hydraulic table over which the cab is run. The motor is of 3 HP., with double wound armature and fields, and drives two wheels of the cab through differential gearing. The controller is of the series-parallel type, and is so arranged that speeds of 3 miles, 7 miles, and 9 miles per hour can be run at full efficiency and without interposing resistance. The cab can be stopped either by the controller or foot brake, and can be reversed. One set of cells suffices for 50 miles.

A. P. H.

Steam-Engine Efficiencies. GUSTAV LENNER.

(Der Civilingenieur, 1896, p. 665.)

The Author draws attention to the great difference in estimating the efficiency of an engine with reference to the quantity of steam used, and with reference to the quantity of heat. Taking the indicator efficiency as the ratio of the indicated work to that done in a Carnot cycle with the same limits of temperature as in the actual engine, a 1,500-HP. triple-expansion engine, with 7·2 atmospheres boiler-pressure saturated steam, tested by Professor Moritz Schroeter, gave an indicated (heat) efficiency $\eta = 0 \cdot 633$, and an indicated (steam) efficiency $\eta' = 0 \cdot 807$. A Sulzer triple-expansion engine of 1,860 HP. and 11·75 atmospheres boiler-pressure saturated steam, gave $\eta = 0 \cdot 629$, and $\eta' = 0 \cdot 854$. The same engine tested by Professor Schroeter, but using superheated steam at a temperature of 231° C., gave $\eta = 0 \cdot 645$ and $\eta' = 0 \cdot 820$.

The working cycle in an engine using saturated steam approximates to, while that in an engine using superheated steam differs essentially from, the Carnot cycle. The Author describes normal cycles for saturated and for superheated steam-engines and uses them for standards for the indicated efficiency of an engine. The engine tested by Schroeter gave $\eta = 0 \cdot 694$ and $\eta' = 0 \cdot 709$ with saturated steam, and $\eta = 0 \cdot 704$ and $\eta' = 0 \cdot 727$ for superheated steam. These figures show clearly that the indicated efficiency of an engine, compared with the normal cycle, is quite different to that compared with the complete Carnot cycle.

It is the general practice to estimate the excellence of an engine by the steam used per I.HP. per hour, and as this gets smaller with increased experience in engine-building, engineers congratulate themselves on the great progress made. That great progress has been made is undeniable, but whether the correct standard to measure the progress has been chosen is a subject for discussion. For example, a Schmidt motor, using steam with 350° C. of superheat, requires only 10 lbs. of steam per I.HP. per

hour, while a triple-expansion engine, using saturated steam at the same pressure, requires 11·3 lbs. of steam per I.HP. per hour. These figures give no indication of the fact that 1 lb. of steam in the Schmidt motor has to be supplied with much more heat than in the saturated steam-engine. This Schmidt motor, tested by Professor Schroeter, gave $\eta = 0\cdot592$ (compared with the Carnot cycle), a value less than that for the Sulzer engine, $\eta = 0\cdot629$.

A. S.

On the Steam Consumption of a Compound Engine.

OLRY and BONET.

(Mittheilungen aus der Praxis des Dampfkessel- und Dampfmaschinen-Betriebes, 1897, p. 101 *et seq.*)

A series of experiments were made on 7, 8 and 9 August, 1894, on a compound steam-engine indicating 200 HP. at 76 revolutions per minute and 6 atmospheres initial steam-pressure. The experiments were to determine the variation of steam-consumption by varying (1) the initial steam-pressure, (2) the work done by the engine, or the period of cut-off, (3) the heat supplied to the steam-jackets.

Two trials were made in the first series, 165 HP. being indicated in each trial, the initial pressures being respectively 5 and 6 atmospheres. The steam used was respectively 16·0 lbs. and 15·0 lbs. per I.HP. per hour.

In the second series two sets of trials were made, with initial pressures of 6 and 7 atmospheres respectively. At 6 atmospheres initial steam-pressure the engine indicated 190, 165, 100, and 55 HP., the corresponding steam-consumptions being respectively 15·6, 15·0, 18·0, and 18·5 lbs. per I.HP. hour. At 7 atmospheres steam-pressure two trials were made, the engine indicating 190 and 100 I.HP., with steam consumptions respectively 15·1 and 15·9 lbs. per I.HP. hour.

In the third series, trials were made at 6 atmospheres and 5 atmospheres initial pressure, and various conditions of jacket heating, the steam-consumption being in most cases reduced by using the steam-jackets.

A. S.

The Diesel Oil-Engine. Prof. M. SCHRÖTER.

(Zeitschrift des Vereines deutscher Ingenieure, 24 July, 1897, p. 845 *et seq.*)

The Diesel oil-engine appears to be the outcome of various theoretical considerations set forth in detail.

The experiments have been carried out with more than usual consideration for accuracy. At full load (about 20 brake HP.) the

amount of petroleum used is stated to have been a little over half a pint of oil, per brake HP. per hour. The analysis and determination of the petroleum used are given in great detail, and it would appear that the petroleum used was probably American.

Another result attained by this motor is that a higher percentage of the heat in the fuel (petroleum) is turned into work in the cylinder when the engine is running at half load, but a less percentage appears as useful available energy; this is seen by the following Table:—

—		Full Load.	Half Load.
		Per Cent.	Per Cent.
Percentage of heat turned into work	Indicated . .	34·2	38·5
	Brake . . .	25·7	22·4

It is further claimed that the governing can be effected in a strictly analogous manner to that of the steam-engine, namely by varying the quantity of petroleum supplied to the cylinder. As illustrating this a diagram is given showing the indicator diagrams taken at various loads from full load to no load at all. Perhaps the chief departure from ordinary oil-engine practice is the high initial pressure in the cylinder, namely, about 550 pounds per square inch, the degree of compression at the end of the stroke bring about 530 lbs. per square inch. There is no ignition arrangement of any kind nor is any atomiser used. It is also claimed that, owing to the complete combustion of the petroleum, the cylinder remains perfectly clean, there being, after a day's run, hardly any dirt whatever on the inside of the cylinder cover, and the cylinder walls within the limits of the stroke being perfectly clean. Further it is said that there is absolutely no smell arising from the products of combustion.

E. C. S.

Comparative Tests of a Spirits-of-Wine Motor.

(Annalen für Gewerbe und Bauwesen, 15 August, 1897, p. 67.)

Recent tests have demonstrated that spirits of wine compares very favourably with other fluids used to generate power in small engines, and an account is given of some trials with spirits of wine conducted by Messrs. Körting at their works in Hanover on the 26th and 27th March of the present year. The spirits employed contained 93 per cent. of alcohol, and had a specific gravity of 0·8149. The engine, which worked very regularly throughout the trials, was driven at 228 revolutions per minute. The diameter of brake-wheel and brake-power used are specified. It was found on the conclusion of the tests that 0·49 litre of

hour. Water for the cooling of the rate of 21·86 litres per I.HP. hour. built for the purpose of these of the same type as the benzene motors With benzene the engine was calculated with the spirits of wine it indicated 9·933 HP. Though, naturally, more heat cylinder than with benzene, it was proved wine is much more completely utilised in the petroleum spirit would be, and there was of premature and late explosions, and of all The cost of spirits of wine per I.HP. hour was only more than the cost of benzene, and it is asserted that, the facts into consideration, if the price of petroleum is the same, the latter is to be preferred for the production of power.

G. R. R.

Tipping Apparatus and Plant for Handling ... at Nassandres.

(Le Génie Civil, ...)

The tipping apparatus ... Chas. Roisin for unloading ... Bouchon at Nassandres, ... terials, and for all ... platform large enough ... upper surface, ... way siding. ... to those ... being lifted ... together so as ... The wagon ...

spirits was needed per I.HP. hour. Water for the cooling of the cylinder was used at the rate of 21·86 litres per I.HP. hour. The engine was specially built for the purpose of these comparative tests, and was of the same type as the benzene motors constructed by this firm. With benzene the engine was calculated to work at 6 HP., but with the spirits of wine it indicated throughout the trials 9·933 HP. Though, naturally, more heat was developed in the cylinder than with benzene, it was proved that the spirits of wine is much more completely utilized in the engine than the petroleum spirit would be, and there was an entire absence of premature and late explosions, and of all dirt and soot. The cost of spirits of wine per I.HP. hour was only 10 per cent. more than the cost of benzene, and it is asserted that, taking all the facts into consideration, if the price of petroleum and spirits is the same, the latter is to be preferred for the production of power.

G. R. R.

Tipping Apparatus and Plant for Handling Beetroots at Nassandres.

(Le Génie Civil, 5 June and 10 July, 1897, pp. 85 and 167.)

The tipping apparatus here described was designed by Mr. Chas. Roisin for unloading beets for the sugar factory of Mr. A. Bouchon at Nassandres, but is also suitable for any similar materials, and for all types of railway wagons. It consists of a platform large enough to carry one wagon, with rails on the upper surface, placed so as to form when untipped part of a railway siding. This platform is carried on curved rockers, similar to those under the ordinary side-tip wagon, and tips sideways, being lifted at the back by two hydraulic cylinders coupled together so as to prevent uneven working.

The wagon to be tipped is run on to the platform, and when tilted is prevented from falling over by a beam along the lower side of the body, supported at the ends by adjustable stops. The lifting cylinders are double acting, so that their motion is entirely under control, and work at a pressure of 71 lbs. per square inch. There is also a side platform which moves with the tip, from which if necessary men can clear out the corners of the wagon. The tipping is done by one man, and from four to eight wagons can be emptied per hour, depending on the nature of the contents. The beetroots are tipped on to a platform below the level of the rails and thence into small trucks at a still lower level. These trucks are hauled up an incline by an endless rope to a raised way running round the storage bins from which the beets are again tipped into the bins. There is a slight fall from the upcoming road at the top of the incline to the return road, so that the trucks run round the bins by gravity. This road has a gauge of 23½ inches, and the trucks a capacity of 26½ cubic feet.

The grips coupling these trucks to the endless cable are described in the second article, and have vertical jaws; they are closed by hand at the bottom of the incline going up and at the top coming down, but automatically drop the cable at the other ends of the incline, so that little manual labour is required. The jaws are closed by an eccentric action, but have also a small play either way in the direction of the cable, which by means of inclined planes causes them to close slightly, the pressure being allowed a little elasticity through the medium of an adjustable spring. Thus, when the truck is started by closing the grip, the jerk of the cable is to some extent taken up by the play of the jaws, which at the same time increase their pressure on the cable.

The first article is illustrated by four views of the installation and a sheet of drawings, while there is also a sheet of four drawings of the grip.

R. B. M.

On the Hygrometric Saturation of the Crust of the Earth.

O. KELLER.

(Annales des Mines, vol. vii., 1897, p. 32.)

The proportion of water existing in rocks, as quarry water, water of impregnation, imbibition, or capillarity, as it is variously called, has been studied by numerous observers, prominent among whom have been the late Sir H. T. de la Beche, M. Delesse, and M. Daubrée. The Author's attention has been directed to this subject during the past ten years in connection with the work of supervising and securing the ground above the numerous subterranean quarries in the neighbourhood of Paris. In 1887, experiments were made upon the chalk taken from a quarry at Bougival, which showed the great susceptibility of that rock for absorbing water, and the great diminution in strength caused by such absorption. The tests were made upon 4-inch cubes, which were subjected to a crushing stress in a hydraulic press, with the following result:—

——	Weight.	Crushing Pressure.
	Lbs. per Cubic Foot.	Lbs. per Square Inch.
1. Chalk as quarried	102	273
2. „ dried at 40° C.	99	740
3. „ soaked in water for forty-eight hours .	120	180

Subsequent investigation, made in the quarry, showed that, in the normal condition of saturation, the rock contained about 23 per cent. of water, and that no reasonable difference was observed

between the different parts of the workings, *i.e.*, that the desiccating effect of the air among the old pillars was very small. The same thing is observed with more compact limestones used for architectural purposes, which, however, have a smaller absorptive power; their average, as deduced from forty-one different kinds of stone, being about 14 per cent. Coal and coal shale contain from 2 per cent. to 4 per cent. These quantities appear to be remarkably constant, and the Author concludes that, apart from a comparatively thin superficial covering, which is exposed to atmospheric desiccation, and whose thickness is necessarily variable with the state of the air, the rocks of the earth's crust, and more particularly those of sedimentary origin, are in a condition of stable saturation. The quantity of water so contained is very considerable, for supposing it, according to Delesse, to amount to 5 per cent., and the permeability to continue down to 20,000 feet, at which level, according to Vogt, the temperature will be 600° C., and the tension of water vapour would counterbalance the upper pressure, the computed volume is about $\frac{1}{921}$ part that of the earth, while the surface water contained in the different ocean basins is about $\frac{1}{327}$ part. The estimate of 5 per cent. only applies to exposed surfaces, and is too small for those areas that are covered by the sea, and from which no evaporation can take place; and the Author therefore considers that the volume of water imprisoned in the rocks, apart from that contained in water-bearing strata, is considerably larger than that of the sea. Such water, owing to its low thermal conductivity, is eminently favourable to the preservation of the internal heat, and by lowering the resistance of the rocks the production of folds and fissures in the strata is facilitated. The Author hopes that the subject, which he has only briefly touched, may attract the attention of other observers to a point in terrestrial physics of practical as well as scientific interest.

H. B.

Coking Coal of Recent Geological Age. R. HOFMANN.

(Montan Zeitung für Oesterreich-Ungarn, 1897, p. 161.)

In view of the importance of having a supply of coking coal in a country like Hungary where the coal resources are not equal to those of iron ore, trials have been made at various times since 1850 to convert the Upper Oligocene coal, notably that occurring in the extensive Zsily coalfield, into coke. On the whole, however, the results have not been satisfactory.

In the year 1884, at Lupény, in the western portion of the coalfield in the so-called seam V, a specially pure brown coal was found, and new coking trials were undertaken. They gave on washing a loss of 11 per cent., and on coking a yield of 61 per cent., with 8·2 to 9 per cent. of ash. Similarly the coal from

seam II could be converted into coke, even in an unwashed condition. After the Government had granted a concession for the construction of the railway from Petrozsény to Lupény, the Urikány-Zsilthaler Hungarian Coal Company was formed, and in 1895 the output of the Company's colliery at Lupény was 215,156 tons. The deeper seams of the west of the Zsily coalfield proved purer, richer in carbon and poorer in oxygen, than seam V. Indeed the brown coal chemically resembled bituminous coal. The output in 1896 amounted to 300,000 tons with a waste of 60,000 tons of small coal, a quantity sufficient for the requirements of a coking plant. The trial on the largest scale was made with 50 tons of coal, and yielded 33·2 to 41·7 per cent. of volatile constituents, 0·2 to 0·48 per cent. of ammonia and 5·4 to 12 per cent. of tar. The proportion of ash in the crude coal amounted to 17 per cent.; it could, however, be reduced by washing to 8·3 per cent. The yield of coke was from 62·26 to 71·20 per cent., with 12·7 to 13·3 per cent. of ash and 2·57 per cent. of sulphur. The coking process was quite normal and the coke was obtained in compact masses. It closely resembled the Karwin and Zabrze coke, and is consequently well adapted for blast-furnace use.

B. H. B.

On Preventive Measures against Dust in the Saarbrucken Mines. H. Dröge.

(Zeitschrift für das Berg-, Hütten- und Salinen-Wesen, vol. xlv., p. 165.)

In March, 1885, an explosion at the Camphausen pits caused the death of 180 men out of 219 men at work underground, and in 1880 and 1890 other disastrous accidents of the same kind at the neighbouring Kreuzgraben and Maybach mines were principally caused by coal-dust. In consequence of these accidents, very complete precautions have been taken for wetting the dust, and in places saturating the coal with water before breaking it down in all the Saarbrucken mines. These are described and illustrated in considerable detail by the Author. The five mines noticed have a joint daily production of 7,310 tons, with a total of 7,810 men underground, of whom 4,040 are day-shift workers. The watering is done by hose and jet from hydrants from 30 to 80 yards apart upon the distributing pipes, which vary in diameter from about 3½ inches to $\frac{8}{10}$ inch diameter, except in the König mine, where they are also used for supplying hydraulic motors, and are made larger, or from 4 inches to 14 inches bore. The pressure varies with the depth and other conditions from 6 atmospheres to 30 atmospheres in the mains, and from 3 atmospheres to 20 atmospheres in the branch lines. The quantity of water used in sprinkling is about 1,000 tons daily. The length of pipes laid in the different mines was, in 1896, about 112 miles, the water

being applied over a length of about 65 miles of workings. The total cost of the system since 1886 has been about £43,000, and the annual charge, which includes new extensions, is about £6,900, which corresponds to about 0·8*d*. per ton of coal.

In addition to the dust-watering arrangements, special rules concerning the use of explosives have been enforced, black powder being forbidden, and only dynamite in water-cartridges and safety explosives (ammonium nitrate powder) allowed. In workings with 1½ per cent. of gas in the air, blastings are forbidden, and various mechanical contrivances, such as the Hardy and Francois power wedges, have been tried, but with no very marked success. The Francke hand boring machine, used in the Mansfeld mines, has been tried, but was not found to give better results than ordinary handwork. In the Maybach mine, with an annual output of 402,600 tons, the extra cost due to watering and the restrictions upon blasting in 1894–95, was computed to be £5,300, or slightly in excess of 3*d*. per ton.

H. B.

English Coal, and its Competition with Foreign Coal.

(Archiv für Post und Telegraphie, 1897, p. 414.)

The export of coke and coal from England to Germany is increasing more rapidly than the gross English export of these materials. It appears that in 1894 the gross export was 33,074,000 tons and in 1895 it was 33,112,000 tons, a rise of only 38,000 tons; out of this quantity Germany took in 1894 the total of 3,894,000 tons and in 1895 a total of 4,144,000 tons, so that this export trade increased 25,000 tons. This circumstance causes anxiety in German commercial circles. The same thing occurred in 1896, the increase in the gross export being for the nine months January to October, only 4 per cent., while during that period the increase in export to Germany was 14 per cent.; the export from England could also be much increased, as only about one-sixth of the amount brought to ground is now sent abroad.

The annual consumption of coal and coke per head of population in Great Britain only increased 660 lbs. between the years 1875 and 1895, while in Germany it increased 1,980 lbs. Great Britain has a world market for British coal, and the production of her colonies and foreign possessions is also increasing, and reached in 1894 the total of 11,368,000 tons. India produced only 1,320,000 tons in 1883, but in 1895 a total of 4,396,000 tons. The author continues by pointing out that the growing output of Canada and the United States will cause those countries to become rivals of Great Britain for the export trade of the world. The modest output of coal in South Africa is also increasing.

Japan is becoming a serious competitor for the coal trade of East Asia, and her output has already reached 1,400,000 tons.

China so far is not a rival, in spite of her immense coal-fields. The exploitation of coal-fields in Amoy by Germans and of the Nankin fields by Chinese has begun. The bulk of the Russian output, of 8,667,000 tons, is produced by the Don fields.

English coal cannot now be delivered and sold at a profit in the Black Sea. England supplies almost all the coal used in Italy, 50 per cent. of that used in Spain and 11 per cent. to 12 per cent. of that used in France. The export of British coal meets competition everywhere, resulting in reduced profit or entire of the trade. The Scandinavian peninsula obtains 90 per cent. of its coal from Great Britain. Coal can be delivered to the German coast more cheaply from Great Britain than from the German coal-fields, and the output of the German pits does not keep pace with the home demand. The Author thinks that the only way of competing with English coal is to lower German freights.

E. R. D.

Extraction of Tellurium at Schemnitz. J. Farbaky.

(Zeitschrift für angewandte Chemie, 1897, p. 11.)

The process consists in boiling tellurium ores from Transylvania in concentrated sulphuric acid. This results in the tellurium, together with the lead, copper, zinc, and some of the silver, passing into solution, whilst the gold and silica remain in the residue. The tellurium is then washed out of the evaporated mass with water containing hydrochloric acid, and precipitated from the filtered solution by sulphurous anhydride. The boiling of the ore is effected in cast-iron pots, the charge consisting of 330 lbs. of tellurides and 770 lbs. of concentrated sulphuric acid. After solution, the mass is heated until it acquires a syrupy consistency. It is then allowed to cool, and lixiviated, in wooden vats lined with lead, with 55 gallons to 66 gallons of water, to which 44 lbs. of concentrated hydrochloric acid is added. The operation is assisted by continued stirring of the mass. The separation of the solution from the auriferous and argentiferous residue is effected by filtration under pressure. The gold and silver are recovered from the residue by cupellation. The filtrate containing the tellurium is run into wooden tanks lined with lead, into which a current of sulphurous anhydride is passed. The sulphurous anhydride answers better as a precipitant than the zinc formerly used, and, purchased in liquid form in iron cylinders, is found to be cheaper than if it is made by heating copper with concentrated sulphuric acid, or by burning sulphur. The operation is completed when a sample of the liquor ceases to give a precipitate with sodium sulphite and hydrochloric acid. The precipitated tellurium contains 72 per cent. to 86 per cent. of tellurium, with oxygen, copper, arsenic, antimony, manganese, iron, alumina, lime, magnesia, and silica. In order to obtain a product 97 per cent. to 98 per cent.

pure, the metal must be again dissolved and precipitated. The metal is melted in earthenware crucibles, and cast in rods. The mother-liquor is absorbed by slaked lime and flue dust, and moulded into bricks, which are utilized in smelting lead, gold, and silver ores.

B. H. B.

The Extraction of Copper from Pyrites. L. Bréda.

(Annales de l'Association des Ingénieurs sortis des Écoles spéciales de Gand, 1896–97, p. 96.)

This is a description of the wet process of extraction of copper at the Hemixen-lez-Anvers works, from pyrite ores containing 3 per cent. to 4 per cent. of copper, based on the principle of transforming the sulphur (chiefly in the form of sulphide of iron) into sulphate of soda, by the addition of salt, leaving chlorides of copper.

The steps of the process are: roasting, and then crushing the ore; roasting with salt; washing, and finally the precipitation of the copper. The first roasting is done in Malétra furnaces, in groups of seven, the ore being raked from one to the other, and the process occupying thirty hours. Each furnace is about 8 feet long, and 2 feet 6 inches wide. After roasting, the ore contains about 5 per cent. of sulphur, in place of over 40 per cent. before being treated. The sulphur which is driven off is used in the manufacture of sulphuric acid. The ore is next mixed with about 18 per cent. of salt, and passes through a crushing machine, and is then again roasted in muffle furnaces. Each furnace can treat about 5 tons of ore at once, the material being introduced through the top, and raked out through side openings. The heat in the muffle should not exceed 500° C., and the gases pass through a long flue to a condensing and washing tower. The ore in the muffles is kept at a dull red heat for about six hours; it is then raked out, and when cool, is placed in masonry trenches, lined with lead, protected by wood, with filters at the bottom formed of bricks and reeds, below which are the draining passages. Here, the chlorinated ore, in quantities of 25 tons, is twice washed with 660 gallons of water at 10° C., then for twenty-four hours with the waste liquor from the precipitating tanks, then with dilute warm sulphuric acid, and finally with warm water. The washed ore then contains only about 0·2 per cent. of copper. The liquor from the trenches is run into a series of eighteen tanks, about 12 feet long and 4¼ feet deep, the first one acting as a settling tank for impurities, while in the remainder, which contain scrap iron or steel, the copper is precipitated. The amount of copper in the waste liquor is only about 1·4 grains per gallon.

The precipitated copper is then washed, and foreign matter sorted out, and in this final state contains from 83 per cent. to 85 per cent. of copper. The paper is illustrated by a sheet showing the details of the chlorinating furnaces. R. B. M.

The Kraft Ironworks near Stettin.

(Stahl und Eisen, vol. xvii., p. 705.)

At Kratzwick, on the left bank of the Oder, about 6 miles below Stettin, a new blast furnace and coking plant has been erected by Mr. B. Grau for Count Henckel-Donnersmarck. The site being a peat moss liable to flooding rendered the use of piling on a large scale necessary, more than 10,000 piles having been driven to depths varying from 40 feet to 55 feet to carry the stone and concrete foundation of the furnaces and stove, which is about 7 feet thick. The furnaces, which have free standing stacks with lattice columns for carrying the charging bell and gas-tube, are 65 feet high, 21 feet 3 inches in diameter in the works, and 10 feet 7 inches in the hearth, with six blast and two cinder twyers. The gas-trap is of the Langen form, with cup and cone and central gas-tube, leading directly into the dust catcher, which, like those of other Silesian furnaces, is of unusual size, being a rectangular box 59 feet high, 41 feet 4 inches long, and 19 feet 10 inches broad, divided into square passages by six cross walls inside, so that the gas has to change direction five times, and travel nearly 300 feet in passing through. The dust separated falls into a tank at the bottom about 30 inches deep filled with water, making a gas-tight seal. Eight Cowper stoves, 77 feet high and 21 feet 4 inches in diameter, are provided for the two furnaces. Four traversing conveyors on Hunt's principle, with a span of 230 feet, are provided for unloading steamers bringing ore and coal, as the furnaces, which are the first of their class built on the German Baltic Coast, are, with the exception of some bog ores, cinders and scrap obtained in the neighbourhood, worked with sea-borne minerals from Sweden and Spain, the coal which is coked on the spot being English, which is to be in part supplemented by supplies from Upper and Lower Silesia; the limestone flux is brought from Rudersdorf, near Berlin. The first charge of coal was coked on the 2nd August last, and the first metal was tapped from the furnaces four days later.

H. B.

On the Condition in which Elements other than Carbon exist in Cast-Iron and Steel. (First Paper.)

AD. CARNOT and GOUTAL.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxxv., 1897, p. 148.)

By using suitable re-agents the Authors have found it possible to dissolve away the iron of cast-iron or steel, leaving untouched the foreign elements or compounds which may be contained in it. Silicon may be separated by the action of dilute hydrochloric acid in an atmosphere of carbon dioxide. It appears to exist princi-

in the form of a silicide of iron, but if manganese is present, nearly the whole of it is combined with the silicon. Sulphur and sulphides can be isolated by dissolving the metal in neutral chloride of copper. There is evidence that, if manganese is present, the sulphur combines with it rather than with the iron. This may explain why it is sometimes advantageous to add ferro-manganese to the metal. Phosphorus can be separated by means of neutral double chloride of copper and potassium, and appears to exist in the form of a phosphide of iron. Arsenic is obtained in the metallic state by attacking the iron with dilute hydrochloric acid in an atmosphere of carbon dioxide. It seems to be simply dissolved in the metal, and not in any way combined with it.

G. J. B.

On the Condition in which Elements other than Carbon exist in Cast-Iron and Steel. (Second Paper.)

AD. CARNOT and GOUTAL.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxxv., 1897, p. 213.)

Continuing their research the Authors find that the re-agents hitherto tried fail to separate manganese from iron when the percentage reaches a certain limit. Copper may be isolated by a 5 per cent. solution of hydrochloric acid under carbon dioxide. It seems to be simply dissolved in the iron. The separation of nickel presented the same difficulties as that of manganese, but, like copper, it appears to be merely dissolved in the iron. Chromium, in quantities not exceeding 2·5 per cent. may be detected with the double chloride of potassium and copper. It is probably present as a carbide of chromium and iron. The same method serves for titanium, which is left behind as an insoluble residue. Tungsten, if present, may be separated as a compound of tungsten and iron by the action of dilute hydrochloric acid under carbon dioxide, and the same process serves for the isolation of molybdenum. To sum up, manganese, nickel, copper, titanium, and arsenic seem to exist in the iron in a state of simple solution, although a portion of the manganese may be present as a sulphide or a silicide. On the other hand, chromium, tungsten, molybdenum, and phosphorus appear to form compounds with the iron.

G. J. B.

On the Properties of Molybdenum Steel. W. VON LIPIN.

(Stahl und Eisen, vol. xvii., 1897, p. 571.)

At the end of 1896 the Author made some experiments upon the comparative behaviour of steel containing tungsten and molybdenum when subjected to similar methods of hardening and tempering. For this purpose ingots weighing about 50 lbs. each were prepared at the Pontiloff Steel Works at St. Petersburg by melting a 0·5 carbon steel with equal amounts of the different metals. These were forged under a 30-cwt. steam-hammer and drawn down to 1-inch square bars, from which the test-pieces, 4 inches long and ½ inch diameter, were prepared in a lathe. The molybdenum steel forged well, but required careful heating, not exceeding cherry redness, the edges of the bar being quite round and free from the flaws and cracks so often seen in hard tungsten steel. The fracture was dull and fine-grained, somewhat resembling that of chromium steel.

The results of the tests are contained in the following Table:—

Nature of Treatment.	Tungsten Steel. C, 0·56; Wo, 3·8 per cent.			Molybdenum Steel. C, 0·55; Mb, 3·72 per cent.		
	Elastic Limit.	Tensile Strength.	Elongation.	Elastic Limit.	Tensile Strength.	Elongation.
	Tons per Sq. Inch.	Tons per Sq. Inch.	Per Cent.	Tons per Sq. Inch.	Tons per Sq. Inch.	Per Cent.
Heated bright red and slowly cooled in furnace	17·1	39·6	15·0	15·0	36·6	18·0
	17·1	41·0	14·7	15·0	36·9	20·1
	15·1	38·7	13·5	..	..	..
Similarly cooled from a dull red heat	16·2	37·4	5·4[1]	15·1	38·0	14·1
	17·4	39·5	17·3	15·3	37·2	14·6
Moderately tempered heated cherry red	19·4	38·1	5·6[1]	16·8	41·5	18·0
	17·5	41·7	10·0	16·6	41·9	16·9
Oil hardened at a red heat	24·1	46·0	12·9	21·7	40·9	17·0
	22·5	41·1	3·5[1]	21·3	41·9	15·0
Oil hardened at a bright red heat	21·2	41·2	4·7	25·0	46·4	11·5
	21·4	41·7	4·4	27·0	53·5	6·4
Oil hardened and reheated cherry red	21·9	42·8	15·0	17·3	37·2	17·0
	21·5	44·0	8·7[1]	18·4	35·8	17·0
	19·4	38·6	15·1	..	..	..
Water hardened at red heat and slightly tempered	50·9	59·6	7·7	42·7	64·9	6·7
	38·0	51·7	7·5[1]	43·2	65·4	6·4
Water hardened and not reheated	..	65·8	1·2	..	49·7	0

From these figures it appears that annealed molybdenum steel is softer than that containing tungsten, and its elasticity and tensile strength are lower. It will therefore not bear the same heat

[1] These samples showed cracks.

as carbon and chromium steels. Oil hardening and tempering has but a slight effect upon the elastic, and none upon the tensile limit, and therefore such a treatment which notably improves chromium steel is almost useless. Oil hardening has a more powerful effect upon tungsten than upon molybdenum steel, but the effect of water is the reverse; the molybdenum steel becomes the harder, although its elastic limit remains low.

Tungsten steel often develops longitudinal cracks both in forging and hardening, while molybdenum steel is free from this defect. In the water-hardened state, the angle at which fracture took place under the bending test was for tungsten steel 100°, for molybdenum steel 160°, but when fully annealed both kinds bent double without breaking. The most valuable property of the molydenum steel seems to be its power of hardening without cracking, which will account for the endeavours which have been made to substitute it for tungsten and chromo-tungsten steels.

H. B.

On Shingling Puddled Balls by Hydraulic Pressure. B. Meyer.

(Stahl und Eisen, vol. xvii. p. 257.)

At the Hyldschinsky steelworks in Silesia, a demand for wrought iron, especially for tube-making, has caused the process of puddling, which had been given up, to be revived; but owing to the proximity of inhabited houses, a steam-hammer could not be used for shingling the puddled balls, and the use of lever or rotatory squeezers was not considered desirable. The Author therefore decided to try the effect of hydraulic-press squeezing, and has adopted the steam hydraulic press of Messrs. Breuer Schuhmacher & Co., constructed in such a manner as to work at the minimum rate of 40 strokes per minute, and having special water cooling, both for the tup and the anvil. After a few months' trial the experiment has proved perfectly successful, the work being done more rapidly and with a smaller expenditure of steam than with a hammer. According to the data collected from several works, the time required for shingling a puddled ball varies from 1 to 2 minutes, and the number of strokes of the hammer from 30 to 80, or in some instances from 70 to 100, while with the press the work is done with from 7 to 11 strokes in from 55 to 70 seconds, giving a very dense and sound bloom. The steam consumption, as determined by condensing the exhaust in a large cistern of water and noting the rise in temperature, was found to be about 97 lbs. for the five balls produced in one heat. But this is subject to some correction for cooling, and the actual amount is probably 15 or 20 per cent. more, or only about one-third of that required by a steam-hammer to do the same work. With eight furnaces making twelve heats daily, the lessened steam consumption corresponds to a saving of about £150 per annum. The iron

obtained is of excellent quality, having a tensile strength of 22·8 tons, and 23·73 per cent. elongation for common, and 27·6 tons and 20·5 per cent. for the extra class, or considerably above that of ordinary puddled iron.

H. B.

Bronze Doors at the Palais de Justice, Brussels. AD. ENGELS.

(Annales des Travaux Publics de Belgique, June, 1897, p. 361.)

These doors form the principal entrance to the Palais de Justice, and were designed by Mr. Van Mansfeld. They are nearly the largest in the world, measuring 33 feet 11 inches by 14 feet 3 inches inside the stone opening, and have a total weight of 15 tons. They consist of an iron fixed framework of joists and angles, and two leaves formed of channels, angles and plates, all covered on the outside with bronze plates, and on the inside with oak. Each leaf is 24 feet 11 inches high, and 6 feet 7 inches wide, mounted on ball-bearing pivots at top and bottom. The bottom pivot has two sets of balls; one of six balls, taking the weight, and another below it of twelve balls, acting merely as a guide; the top pivot also has twelve balls, and takes no weight. There are very massive screw adjustments to the bearings, both at top and bottom. The total weight of each leaf is 6 tons; the balls are 0·62 inch diameter, and tests of similar ones withstood a pressure of 10 tons each, without deformation, 20 tons with deformation, and crushed under 23·2 tons. The bronze plates and ornamentation are so arranged that the joints are as far as possible concealed. The plates covering the lower portion of the door frame are 11 feet 6 inches long, the joint being thus too high to be perceived, while the joints on the leaves are covered by the ornamentation. The largest moulds for the bronze plates measured 14 feet 9 inches by 6 feet 6 inches by 4 feet 11 inches, and weighed 20 tons, so that the casting of them was no easy matter. The bronze used consisted of 91 parts copper, 3 tin and 6 zinc, the two latter being first melted with their weight of copper, and then again with the necessary additional copper. By this means the alloy obtained was very uniform, and free from spots in the finished castings.

The oak on the inside of the door is in large pieces, secured to the framing by the same bolts which hold the bronze. After some discussion, it was decided to thoroughly clean the outer bronze surface, leaving the toning down to time, and the gates now have the appearance of dull gold. The doors are very easily opened and shut, and when closed the meeting joint is almost imperceptible. Accompanying the Paper are: a photograph of the finished doors, a view during erection, and three sheets of drawings, two being details of construction and pivots, and one comparing the dimensions of this and the five other largest existing doors.

R. B. M.

Electricity from Carbon without Heat. WILLARD E. CASE.

(Industries and Iron, 1897, vol. xxii. p. 265.)

The cheapest material at disposal for the production of electricity is carbon; but in the methods now practised, of converting the potential energy of coal into heat, the inevitable waste is such that in place of the theoretical quantity of coal, viz. 0·185 lb. required to generate 1 HP.-hour of electricity, the average consumption in large electric-light plants is 4 lbs. per HP. hour. To avoid this waste the direct conversion of the potential energy of carbon into electricity is, in the Author's opinion, a *sine quâ non*, and he sees no reason to doubt the possibility of the discovery of a cheap substance capable of acting on coal and developing electrical currents instead of heat.

In systems wherein external heat is employed to assist the direct production of electricity from carbon, such as the Bradley and the Jacques cells, the theory of action appears to be still imperfectly understood, and the effects produced are erratic. The electromotive force apparently depends on the temperature, and is increased when air is blown through the electrolyte. By employing a cell of nickel, as proposed by Bradley, charged with the materials (carbon and caustic soda) used in the Jacques cell, it was demonstrated that during heating the voltage rose to 1·16, but receded to 0·3 volt at a critical temperature above red heat, rising again to 1·16 on cooling, and finally dropping once more when the caustic soda solidifies.

The Author inclines to the opinion that the solution of the problem of electricity from carbon without heat should be approached in a different way, and that a lesson might be taken from the relatively high efficiency of the animal body as a machine for converting the potential energy of carbon into work. Furthermore, the natural preparation of the generating material (food) in the body, by transformation into a condition in which it can be readily oxidised at a low temperature, points to the desirability of preparing the material for use in carbon-consuming batteries. In the cell devised by the Author, consisting of a carbon electrode and one of platinum, immersed in sulphuric acid, the addition of potassium chlorate results in the formation of peroxide of chlorine, which is decomposed by the carbon, the latter being oxidised without heat, whilst chlorine is liberated at the platinum pole, and a 0·4-ampere current with an electromotive force of about 1·3 volt is generated. A similar action is produced by supplying gaseous peroxide of chlorine to the cell. These results appear to indicate that the number of foot-lbs. of energy per lb. of carbon is greater than determined by Andrews, since the electromotive force due to the oxidation of carbon is generally assumed, on his basis, to be about 1·05 volt. The electromotive force of the above cell may be still further increased by concentrating the oxidising agent, but this is attended with danger on account of the explosive nature of the gas.

This typical instance shows the possibility of direct conversion, at normal temperatures, of the potential energy of carbon into electrical energy by the aid of oxygen in a state of loose combination, and the Author therefore concludes that the process only awaits the discovery of a cheap carrier of oxygen or an easily oxidised carbon compound to become practically feasible, without the necessity of resorting to heat with its attendant waste due to the influence of the second law of dynamics.

C. S.

Gaseous Fuel as a Means of Cheapening Electricity.

NELSON W. PERRY.

(Industries and Iron, vol. xxii., 1897, pp. 134 and 176.)

In view of the facts that, whereas electricity can be produced at the generating station more cheaply than gas at the gasworks, the high cost of distribution so enhances the price of the former that it is cheaper for a consumer to pay the gas manufacturer's profit and produce his own electricity by the aid of a gas-engine than to purchase it from an electric company; and, furthermore, that gas for use as fuel can be distributed through mains at a much higher pressure than for illuminating purposes, and therefore in greater quantity at less cost, the Author proposes that gas fuel should be used for electric power and lighting plant. With this object he would establish central gas-producing stations in positions where land is cheap and accessible for the discharge of coal, and there erect large gasholders, distributing the gas to local generating stations provided with smaller gasholders, so that the gas-mains could be worked to their maximum capacity. Steam-engines and boilers would then be replaced by gas-engines, occupying less space, and entirely obviating stand-by losses. If found advantageous, storage batteries could be substituted for some of the local gas-storages, and thus all the plant, and consequently the invested capital, employed to the best advantage, leaving only the distributing mains to be worked under a low load-factor. The resulting economies would permit of better service with the same outlay for copper, and the extension of supply to hitherto inaccessible districts. A considerable saving (4*s.* to 6*s.* per ton) would be effected in the coal bill, owing to the lower price of gas coal, as well as on delivery charges and the expense of removing the ashes.

The most profitable gas to produce depends on the distance it will have to be distributed, gas of high calorific power being best where this is considerable, whilst a low-grade, such as Dowson gas, would be most economical when consumed on the spot, though not so—by reason of the higher frictional losses, and greater volume necessary—in the former case.

C. S.

Application of the Storage Battery in Electric Traction.

CHARLES HEWITT.

(The Electrical World, vol. xxix., 1897, p. 204 *et seq.*)

In a Paper read before the Engineers' Club of Philadelphia, the Author discusses the subject of storage batteries for electric traction purposes in the three chief directions possible, viz.:—(1) The use of batteries on the motor-cars themselves; (2) their application to long lines for regulating line pressure, &c.; and (3) their use in the main power-house.

With regard to the first, he is unable to show any good results whatever; tests on an average line indicated not only a much heavier engine output per car (18·8 HP.), as compared with the average on similar trolley lines (10 to 12 HP.), but also a marked inefficiency and short life in the battery—positive plates seldom lasting more than three or four months. The lead grids become rapidly disintegrated owing to their necessary lightness and the heavy current densities.

The combined systems of car, accumulator and trolley (such as those used in Hanover and Dresden) he looks upon as makeshifts, due to local conditions and only sufferable until the authorities consent to the erection of trolley wires throughout. Meanwhile this arrangement entails heavy loads upon the feeders, which must supply current not only for operating cars upon the trolley sections, but also for charging the batteries at the same time. Dealing next with the second application of storage batteries—their use in connection with long lines as pressure regulators—he points out that there is no restriction as to size of plate (as must be the case with batteries fixed on the cars), and therefore the battery is not subject to the great loss of efficiency due to the fall of electromotive force on discharge, nor yet to the disintegration and consequent short life of plates with light grids. A full description of the large battery installed by the Union Traction Company of Philadelphia then follows; this battery is situated in a substation nearly 10 miles from the power-house, and by its erection saved a large outlay otherwise rendered necessary either in additional feeders or another power-house. The comparative costs are stated to be as follows:—for extra feeders, £54,000; for a secondary power-house, £17,000; whilst for battery, land and building, the total cost was only £6,700.

In the application of a battery to the power-house itself, it becomes a load regulator rather than a pressure regulator, as in the last case; and the object of installing a battery is to equalize the load on the generators so that the engines may run at the point of maximum efficiency.

F. B. L.

The Dependence of the Capacity of a Secondary Battery upon the Discharge Current. Prof. W. PEUKERT.

(Elektrotechnische Zeitschrift, 1897, p. 287. 1 Fig.)

The Author alludes to the well-known fact that with a small discharge current the capacity of a secondary battery is higher than with a large discharge current, and explains it by saying that with a low discharge more of the active material can take part in the chemical changes. In order to determine the relation between the capacity and the discharge current the Author made a series of experiments five years ago on a Correns battery. The capacity was 90 ampere-hours with a discharge of 30 amperes, and the discharge was always continued until the same percentage of fall in the potential was noted, while the charge current was always the normal current for the particular size of cell. From the results obtained the Author deduces the empirical formula $J^n \cdot t = \text{constant}$, where J is the discharge current and t the duration of time in hours. This equation holds good not only for the Correns cell but also for all other lead cells, the exponent w varying however with the type of cell. From recent experiments which have been made, the average value of n appears to be 1·47. The value of n for the Hagen accumulator is 1·35, but for the rapid discharge type 1·48, and the Author gives similar values for the Pollak, Correns, Tudor, Khotinsky and Gülcher cells. If K is the capacity with a discharge current J during the time t, then the following equation holds good, $K_1 = K\left(\frac{J}{J_1}\right)^{n-1}$.

E. R. D.

Report on the Precautions to be taken in the Installation of Electrical Conductors near Powder Magazines.

Committee: Messrs. BERTHELOT, CORNU, MASCART, LIPPMANN, DEPREZ, BECQUEREL, POTIER, D'ARSONVAL, VIOLLE.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxxiv., 1897, p. 1211.)

In a letter dated January 21, 1897, the Minister of War asked the Academy what precautions should be taken in the installation of conductors carrying a current in the neighbourhood of powder-magazines. Attention was specially directed to the four following points, namely, (i) the possibility of modifying the regulations of the circular of December 28th, 1858, as far as telegraph and telephone lines are concerned; (ii) the general regulations to be adopted with regard to other conductors of electric energy; (iii) the possibility of lighting the precincts of the magazines with incandescent lamps; (iv) the use of electric bells in the sentry-boxes.

With regard to (i) and (ii), the Committee are of opinion that telegraph and telephone conductors, since they are liable to be struck by lightning, ought not to be treated differently from other conductors. A wire conveying a current is not in itself a source of danger save to objects in its immediate neighbourhood. A distance of 10 metres is sufficient to prevent risk in the case of subterranean lines. Air lines, which may become displaced by accident or by storms, should be at such a distance as to render it impossible for them to fall across the magazine. In general, 20 metres may suffice.

(iii) If it is necessary to light the interior of a magazine containing explosives, by far the least dangerous illuminant is the incandescent lamp. The current should be led in by a subterranean cable, and the conductors in the interior of the building should be covered with an insulating coat of sufficient thickness, enclosed in a metallic covering. All keys and switches, as well as fuses and cut-outs, should be outside the building. All lamps should be fixed and protected by glass coverings. The pressure should not exceed 110 volts.

(iv) Electric bells, which require only a small current, need no special precautions if the wires are led underground, save to place lightning conductors on the sentry-boxes. If the lines are aerial they must have lightning arresters at each end and lightning conductors every 100 metres, with good earth connections.

The Committee recommend the modification of the circular of December 28th, 1858, in accordance with these suggestions.

G. J. B.

The Sag of Iron and Bronze Telegraph Wires. H. Dreisbach.

(Elektrotechnische Zeitschrift, 1897, p. 147. 2 Figs.)

The German telegraph specifications require that the sag of the line shall be such that at the lowest temperature (which is taken as $-25°$C.) the stress upon the wire shall not exceed one-fourth of the breaking stress. The safe tension and weight of wire being known, the span and sag are approximately obtainable from the usual tables. Calculations of the variation in the sag of wires at higher temperatures cannot be obtained merely from the coefficient of expansion of the metal, as elasticity must also be taken into account. The decrease of tension with increase of heat is followed by elastic compression acting against the extension due to the heat, and if elasticity be neglected in calculations too great a value is obtained for the extension. The Author points out that, as bronze wires are becoming more freely used on posts where iron wires are already hung, it is desirable to have more accurate information as to sag for wires of these materials at various temperatures. He then gives in tabular form values of tension

and sag for given temperatures and spans of 54 yards and 108 yards, and points out that as the specific gravity of iron wire is to bronze wire as 782·891, a tension of 6·35 tons per square inch, the iron will correspond to a tension of 7·2 tons per square inch in the bronze. He represents in the form of curves the values also set forth in tables, and concludes that there is no reason for prohibiting the use of bronze wires on the same posts as iron wires from the fear that the variation in the extension of the two metals might result in the wires touching each other when raised to high temperatures in summer.

E. R. D.

The Improved Aron Electricity Meter. Dr. H. Aron.

(Elektrotechnische Zeitschrift, 1897, p. 372. 11 Figs.)

The Author states that the improved apparatus depends upon the same principle as his earlier apparatus, namely, on the change of duration of the swing of a pendulum according to consumption of current. After recounting the disadvantages of his old clockwork arrangement, the Author points out that in the present type these have been so greatly diminished that the meter has been accepted by the Government Calibration Commission as satisfactory. It differs from the earlier types in the following points:—(1) It is wound up electrically; (2) it has a very small pendulum, so that it can be easily carried without being stopped, and starts easily as soon as the potential is available; (3) it possesses an arrangement to eliminate errors in indication. The Author then proceeds to give a detailed description of the various parts of the apparatus with the help of the figures, and to propound the theory and calculations upon which the design is based. The meter can be used either for direct or alternating current, and for the latter has the special advantage that it is a good wattmeter, being independent of the frequency and taking note of the lag; the winding-up mechanism is designed for some particular frequency, the meter itself is, however, quite independent of it. The apparatus will record any current from zero upwards, and the Author considers that it is superior to other apparatus as it contains no permanent magnets, is independent of friction, and is not materially affected by the temperature.

E. R. D.

A New Recording Apparatus for Submarine Cables. Ader.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxxiv., 1897, p. 1440.)

The Author's form of recording apparatus for submarine telegraphy is on the principle of the D'Arsonval galvanometer. A simple straight wire, about 0·02 millimetre in diameter, the tension of which can be suitably regulated, is placed in a powerful

magnetic field between the poles of a permanent magnet. Owing to its small mass, this wire is able to follow the changes in direction of the current with great rapidity, and its movements are recorded by photography. For this purpose a small hole is made through both pole-pieces, and the shadow of the wire is projected by the light of an ordinary lamp on to a slit, behind which is a moving band of gelatino-bromide paper. In order that the shadow may be sufficiently definite, a small piece of pith from the shaft of a feather is threaded on the wire, the oscillations of which are recorded in the form of a sinuous curve upon the sensitized surface. Tested on the cable from Brest to Saint-Pierre it was able to receive 600 signals per minute, while on the cable from Marseilles to Algiers a speed of 1,600 signals per minute was attained, whereas the receiving instruments usually employed were not able to exceed 600 per minute.

G. J. B.

Foresight in Electrical Engineering. J. E. Woodbridge.

(Cassier's Magazine, 1897, p. 142.)

The Author points out the necessity for putting down the most modern plant in electric-lighting stations, and alludes to the miscellaneous assortment of apparatus to be found in some American installations, where it is usual to find a steam plant consisting of various types of boilers and dynamos of the alternating, direct and 500 volts type for tramway work, all driven by belting from a shaft actuated by engines of the most various kinds. Each dynamo often feeds its own special distributing circuit, and the Author illustrates this by the analogy of a water-company, which might put down special pumps and sets of mains for each of the various purposes for which water is used. He compares this with European practice where, especially in Germany, the utmost care is taken to get the most lasting and efficient plant. This is partly explained by the more settled conditions of the towns and their comparatively slow growth. Rash speculative schemes are not allowed, and there are far more municipal stations in Europe than in America. He cites the franchise of the Berlin Electric Works Co. as an example. This company is required to pay 10 per cent. of its gross receipts as rental for the use of streets for its conduits, also one quarter of its net profits over 6 per cent. The rates for street lighting are very low compared with those in America, the difference in the nature of investment in Europe and America is also a prominent factor. While in the United States it is generally speculative, calling for large and quick returns, in Europe a safe investment and therefore low rate of interest is desired. He then cites the buildings of the International Electric Co. at Vienna, and the Tivoli Works at Rome. He considers the

transformer as used in the United States a source of great loss and prefers the sub-station system. It is likely that the irrevocable determination of methods in Europe will prevent as rapid advances in the future as in America.

E. R. D.

Recent Progress in Arc Lighting. ELIHU THOMSON.

(Electrical World, vol. xxix., 1897, p. 762.)

Series arc-lighting has of late years tended towards the use of high-voltage machines working 125 to 150 lamps, with separate pairs of wires from the machine to the switchboard for each circuit. If overhead wires are employed the inductional effect upon telephone systems is much increased. The Author thinks that the immediate future of series lighting will involve the use of large dynamos, say up to 300-lamp capacity each, coupled direct to steam engines; also that series lighting will continue to prevail in extended districts, however much constant potential arcs (open or enclosed) may come into use in districts supplied with continuous low-pressure current from underground mains.

He next discusses the employment of rectifiers for an alternating supply, whether single or polyphase, and speaks very favourably of their use, since they allow the generation of current in a station by means of large and efficient direct-connected dynamos running at full load, or nearly so, throughout the period of lighting.

In regard to the question of installing two or more lamps across the mains of a constant potential continuous-current circuit, the Author lays great stress upon the use of good carbons for successful working. A good cored positive and a solid negative are essential. There are undoubted advantages in this method, though it is very inelastic in regard to shunting any lamp on a branch, except by replacement with a wasteful resistance.

Alternating currents may be made to operate arc-lamps in series by either of two methods:—on a constant potential system, say at 1,000 volts, with branches each containing, say, thirty-five lamps in series, or by transforming, so as to feed the lamps in series with a current of constant, or nearly constant, value. In the former arrangement, means must be provided for shunting or extinguishing lamps; this is usually done by the help of a properly proportioned resistance coil wound upon a laminated core.

Enclosed arcs are next dealt with, and their numerous advantages detailed; but it is pointed out that they do not avoid the use of choking resistances. From experiments made by the Author, he considers that with either open or enclosed arcs at ordinary current strengths of from 5 to 10 amperes, the steadying resistance is required to cause a drop of about 15 to 20 volts. The remainder of the Paper contains a treatment of such further topics as the running of single alternating-current arc-lamps on

constant potential circuits by the help of a transformer, or compensator, to give any desired voltage; the efficiency of the alternating arc as a source of light, in regard to which the Author considers that with flat-topped waves the limit of periodicity falls much below 40 per second; in fact, if the reversal, or passage through zero is quick enough, almost any reduction of periodicity would become possible; and, finally, some general results obtained from tests upon different types of arcs and lamps.

Anongst the latter may be mentioned the following:—the larger the arc, or the larger the current in it with a normal voltage, the more efficient is the light production; the use of a cored upper carbon appears to raise the efficiency to a moderate extent; with continuous-current arcs (taking the light emitted downwards as alone useful) the expenditure per mean useful candle is about ½ watt with naked arcs, and with enclosed arcs from 1 to 1½ watt (due to absorption); a 16-ampere 25-volt naked alternating-current arc used 1·49 watt per mean spherical candle, or for mean useful candle below the horizontal 1·12 watt, which was reduced to 0·8 watt when a porcelain reflector was placed above the arc. With an enclosed alternating arc, the mean consumption is about 2 watts per mean useful candle.

This apparently greater economy of the continuous-current arc is to some extent balanced by the loss in regulating resistance—all the above values being for consumption at the arc.

F. B. L.

The Use of Condensers with Alternating Arc-Lamps.

GEORGES CLAUDE.

(L'Industrie Électrique, 1897, p. 249.)

After pointing out the difficulty of operating arc-lamps with simple shunt coils by means of alternating currents, in consequence of the self-induction in such coils (the current is not able, as may be readily understood, to increase as rapidly as the difference of potential), the Author gives some details of results obtained by him with a Brianne arc-lamp, with which he found that the current varied from five to ten times less quickly than the difference of potential, even though the periodicity was no more than 42 per second.

He proposes to overcome this difficulty by means of a condenser inserted in series with the shunt coil; and further experiments in this direction gave results of a much more favourable character, the current now varying about twice as quickly as the difference of potential (or which is practically the same thing, the length of arc). Of course due precautions must be taken to ensure approximate equilibrium of the opposing forces, in the shunt coil and con-

denser respectively, but this is not difficult, nor is a massive condenser required. The Author mentions a diameter of 10 centimetres (say 4 inches), with a thickness of 3 centimetres (say $1\frac{1}{4}$ inch) as being sufficient for such a disk condenser.

F. B. L.

A New Optical Method of Studying Alternating Currents.

H. Abraham and H. Buisson.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxxv., 1897, p. 92.)

Various optical methods of studying alternating currents have been based on the fact discovered by Bichat and Blondlot, that there is no appreciable interval between the rotation of the plane of polarization and the establishment of the magnetic field that causes it. The Authors propose a modification of the apparatus employed by Crehore[1] and by Pionchon.[2]

Iodide of mercury in alkaline solution, of which the magnetic rotation is considerable, is contained in a glass tube with glass ends. This tube is encircled by two precisely similar coils placed end to end. At one end is a half-shadow polarizer, and at the other a Nicols' prism, serving as analyzer. A small telescope is focussed on the polarizer. The source of light is the spark from a condenser charged by an induction coil. The primary of this coil is connected with a split ring on the axle of the machine producing the alternating current, and a brush, which can be set in any desired position, completes the circuit, which is thus broken at the same point in each revolution, producing a spark of great intensity and short duration in the secondary. In making an experiment the analyzer is first turned until the illumination in both halves of the field is equal. The alternating current is sent through one of the two coils upon the tube and a continuous current through the other, the intensity of the latter being regulated by a rheostat until the illumination is again equal on both sides. The continuous current, as measured by an amperemeter, is then equal to the instantaneous value of the alternate current. The Author gives as an example the current curves of a four-pole dynamo making sixty periods per second in connection with a transformer.

G. J. B.

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[1] *Physical Review*, vol. ii. p. 122.
[2] Comptes Rendus de l'Académie des Sciences, vol. cxx. p. 872.

The Rating and Testing of Safety-Fuses.

FREDERIC A. C. PERRINE.

(The Electrical World, New York, vol. xxix., 1897, p. 161.)

The Author mentions first the experiments already made on fuses when depended upon to rupture a current-carrying circuit, emphasizing the fact that it is impossible to construct a fusible link with so small a time function as to protect a circuit from a great rise of current under all conditions. Traced out from the method of Kennelley for obtaining the heat absorbed by a wire in a definite time, the Author then arrives at the following expression for current which will melt any fuse in time T—

$$\sqrt{\frac{C}{T\,C'} + \frac{C'}{C''}} \text{ (where C, C}' \text{ and C}'' \text{ are constants),}$$

from which it appears that the melting current tends to vary inversely as the square root of the time.

He considers therefore that the true method of testing fuse wires is to measure the temperature of the wire which is supposed to be protected, as the current in the circuit is increased. The proper current for a given wire should be so chosen that double its value does not increase the temperature of the wire more than 75° F.; and the proper fuse to protect a wire from overheating is obviously one which when continuously heated will melt when the current supposed to be carried by the wire is more than doubled, provided that this fuse will also melt under the influence of a greater current before the temperature of the wire exceeds 75° F. from the heating effects of the same current.

The resistance and radiating surface of the fuse must be such that its gain of heat per unit of current is more rapid than that of the wire it is protecting.

F. B. L.

The Arrangement of Lightning Conductors. K. R. KOCH.

(Elektrotechnische Zeitschrift, 1897, p. 232. 2 Figs.)

The Author refers to a report upon the work of the German lightning conductor commission by Mr. Nippoldt which appeared in Elektrotechnische Zeitschrift, 1897, p. 113, and notes with satisfaction a proposal by Mr. Findeisen to use the metal ridges and gutters of the roofs of agricultural buildings as lightning conductors. According to the text-books, the enormous resistance caused by rusty joints would prevent effective use of bars of old iron, and the Author made a test on a conductor consisting of angle-iron and bars, and found its resistance to vary between

100,000 ohms and 300,000 ohms. The practical efficiency of such a piece of apparatus can only be explained by supposing the resistance to be lower at the moment when struck by lightning. He then refers to the observations of Lodge, Branly, and Minchin, which tend to prove that under high potentials a discontinuous or badly jointed conductor may become a good conductor. The Author considers that the ridge of a roof and the rain-water gutters and pipes would make an efficient conductor of cage form, and he experimented with a rusty iron chain several yards long to represent a badly jointed conductor; this was put in a room 30 yards to 40 yards from a room where two accumulators and a galvanometer were placed. When an electric spark was produced near any part of the chain, the galvanometer needle rapidly moved to an extent showing that the resistance of the conductor had fallen to $\frac{1}{1000}$ of its value before the spark occurred. Other experiments with a chain on the roof of the technical school are described where the fall in resistance was to $\frac{1}{10,000}$ of the original value. The Author then describes his own method, which consists in running a conductor along the ridge of the roof, providing there two points and taking conductors down to earth-plates sunk until the ground water is reached. In this manner the house will be protected, but water- and gas-mains must, if brought into the house, be put in connection with the conductor, and telephone, telegraph and high potential electric conductors, separately protected elsewhere. If the work must be carried out cheaply ordinary galvanised iron telegraph wire may be used. Points tipped with gold or platinum are quite superfluous, and the experiments by Mr. Precht under Professor Hertz are quoted. It is quite safe to cramp the conductors direct to the walls of the building and soldered joints in the wire should be avoided. The cost of the whole for a house 32 feet high, and covering 2,150 square feet area, should not exceed fifteen or twenty shillings.

E. R. D.

A New High-Tension Lightning Arrester. H. Görges.

(Elektrotechnische Zeitschrift, 1897, p. 214. 7 Figs.)

This is a Paper read before the German Society of Electricians upon a new form of lightning arrester, brought out by Messrs. Siemens and Halske of Berlin. The Author points out that high tension distribution is largely carried on by means of aerial conductors; he considers that a lightning arrester should be free from self-induction, and should automatically extinguish the arc formed by the lightning. In his opinion these features are obtained in the apparatus described, which consists of two bent copper wires placed opposite each other; the bottom part of each wire is horizontal, then follows a vertical part which gradually slants away; the space between the wires is thus a kind of V with

inwardly curved sides. Each wire is held by cast-iron caps cemented into porcelain insulators, one wire is connected to the line and the other to earth. If an arc is formed it moves upwards and must necessarily become longer, and it is extinguished in a few seconds. The Author then compares this new bent wire form with the earlier form brought out by Elihu Thomson, in which each of the two parts consisted of a flat plate with a curved edge; he states that unless arrangements be made to blow out the arc by means of a magnet in the Thomson form it would persist at the lower part; the new apparatus works best at high potentials and is not intended to be used with potentials below 2,000 volts.

E. R. D.

On the Magnetic Properties of New Kinds of Iron.

Dr. A. Ebeling and Dr. Erich Schmidt.

(Elektrotechnische Zeitschrift, 1897, p. 276.)

Dr. Ebeling had given data on the same subject in Elektrotechnische Zeitschrift, 1896, p. 535, and now gives the results of further experiments. The first part deals with cast material, and the second with results of the so-called Steinmetz coefficient of magnetic hysteresis. The results on cast materials were made by the yoke method. The capacity for magnetization varies little for these kinds of iron when the limit of saturation is approached. Out of forty-five test-pieces, the greatest difference in induction was 8 per cent. and only 4 per cent. if one test-piece be left out; for this reason it is sufficient to know the value of the coercive force and the loss of energy by hysteresis in order to judge of the magnetic value of a test-piece in a strong field. It appears that 24 per cent. of the specimens had a coercive force of 1·5 C.G.S. units to 2·0 C.G.S. units, while 18 per cent. had a value of 3·1 C.G.S. units to 5·3 C.G.S. units. The Authors then give, in the form of a table, comparative values of the chief magnetic data for a number of varieties of cast material compared with forged Swedish iron. The results prove that test-pieces cannot be compared by one quality alone, as for instance, permeability, as the same results are given by materials which differ greatly in other respects. Tests were then made on the homogeneity of the test-pieces, and it was found that those pieces which showed good electrical conductivity were also magnetically homogeneous. Other tests prove the great value of annealing to improve the magnetic qualities of some cast steels which are then rendered scarcely inferior to the best soft irons; other test-bars were hardly improved at all, and no law can be deduced, as the exact method of production of the materials was unknown. Test-bars cut out of the centre and the edge respectively of sheet-iron plates gave very different results. The

remainder of the Paper deals with the Steinmetz coefficient of magnetic hysteresis, and the experimental results obtained with various test-pieces are compared with similar values obtained by other experimentalists.

E. R. D.

On the Absorption of Electro-Magnetic Waves. A. Righi.

(Nuovo Cimento, 1897, p. 466.)

In the course of his experiments the Author found indications of an absorption of electro-magnetic waves corresponding to the absorption of light in passing through certain substances. This he has succeeded in demonstrating as follows: An oscillator is fixed in the focus of a parabolic reflector opposite a plane sheet of metal. In the path of the electro-magnetic waves is a large sheet of glass fixed diagonally so that the rays, which pass through it on their way to the metal plane, are reflected on their return sideways on to a resonator, also in the focus of a parabolic reflector. In front of the sheet of metal he places a plate of the substance to be examined. If there is any absorption the effect on the resonator is diminished. He measures the amount of this diminution by ascertaining the angle through which the resonator must be turned to extinguish the sparking with or without the plate. Sulphur, ebonite, paraffin, and ordinary glass produce no absorption. Mirror-glass, marble, and pine-wood absorb a considerable percentage of the radiations, the amount depending, in the case of the wood, on the direction of the grain.

G. J. B.

A New Electrolytic Condenser of Great Capacity. Ch. Pollak.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxxiv., 1897, p. 1443.)

The formation of a superficial coating of high resistance upon a sheet of aluminium employed as positive electrode in a bath of dilute sulphuric acid was observed by Winkelman[1] and also by Ducretet.[2] A tension of 40 volts is, however, the maximum that can be employed with acid solutions. The Author has succeeded, by using alkaline liquids, in making a condenser of very great capacity in comparison with its size capable of withstanding a pressure of 140 volts. A perfectly uniform coating of oxide being essential, the Author forms the plates by a special process, of which no details are given. The plates thus prepared, when treated as positive electrodes in an alkaline solution, become covered with an extremely thin layer of crystalline oxide capable

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[1] Annalen der Physik und Chemie, vol. xx., 1883, p. 91.
[2] Comptes Rendus de l'Académie des Sciences, vol. lxxx. p. 280.

of acting as a dielectric for all pressures below the above-mentioned limit. If the apparatus is merely to be used as a condenser in circuit with a direct current, the negative electrode may be made of some other metal, such as lead. With an alternating current, such an arrangement only allows one phase to pass, and may be used as a commutator. By combining four of these condensers in a manner analogous to the four valves of a double-action pump, both phases of an alternating current can be utilized.

G. J. B.

Vacuum-Tube Lighting. M. A. Edson.

(Industries and Iron, vol. xxii., 1897, p. 292.)

An essential preliminary step to the solution of the problem of efficiency in lighting is to determine what constitutes good illumination. For indoor lighting this implies plenty of light diffused throughout the room without a single point of light being visible; and, moreover, light of a colour conforming to the colour scheme of decoration without however being injurious to the eye. These conditions are best fulfilled by diffused bright sunlight, and the latter is therefore the model on which future methods of illumination should be based instead of on the light of the glowworm as formerly supposed.

In vacuum-tube lighting, either high potential is necessary, or a high rate of change per unit time, the objection to the former in existing systems being the danger to which the persons working the apparatus are exposed. The present devices for securing a high rate of change are faulty, the Moore system being both uneconomical, requiring a high vacuum (difficult to maintain), incapable of dealing with a large amount of energy, and liable to leakages as well as to disintegration of the contacts; and the movement of a wire in a magnetic field, as designed by Tesla, cannot produce the desired result, the object to be obtained being to impart to the atoms within the tube a succession of rapid blows and not a merely increasing push in opposite directions.

The threshing out of the matter really requires the co-operation of specialists in the theory of illumination, chemistry, and the design of electrical apparatus.

Finally, the Author refers to an ideal, though apparently visionary, method of illumination, which requires the discovery of a substance capable of being mixed with the pigments of wall-paper without masking their colour in daylight, but emitting—under the influence of high-frequency low-potential impulses—a light equal to about 1 candle-power per square foot of surface and allowing the true colour of the pigment to be seen. The field of research offered by the new compounds obtained by electro-chemical means is indicated as a likely one for the accomplishment of this aim.

C. S.

A Mercury Contact-Breaker for large Ruhmkorff Coils.

E. Ducretet and L. Lejeune.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxxiv., 1897, p. 1342.)

This contact-breaker is a modification of those of Gordon and Longe. It has a cup, the lower part of which is of small diameter, to contain the mercury, so as to avoid lateral oscillations, while the upper part is wide and capacious, so that the alcohol may not easily catch fire. Contact is made by a plunger working in a slide and driven by an eccentric pin on the shaft of a small motor. The reciprocating parts are balanced so that a high speed can be attained, and a rheostat is used to regulate the velocity. Splashing is prevented by a cover, through which the plunger works, and the mercury cup can be adjusted to the proper level by means of a rack and pinion without stopping the machine.

G. J. B.

The Berthelot-Mahler-Kroeker Calorimeter.

(Mittheilungen aus der Praxis des Dampfkessel- und Dampfmaschinen-Betriebes, 1897, p. 54.)

In estimating the calorific value of fuel by the usual calorimetric methods, the products of combustion are cooled down to about 20° C., and the latent heat of the contained water is therefore included in the measurements. For raising steam in boilers, however, the products of combustion are discharged into the chimney at a temperature of 200° C. or upwards, water contained in the fuel escapes as vapour, and the estimated calorific value of the fuel is therefore too high. This error can be avoided by determining the quantity of water in the escaping gases.

The calorimeter designed by Dr. K. Kroeker is adapted for this purpose. It is of the bomb type; the fuel is used in the form of small briquettes, each weighing 1 gram, and is placed inside the bomb, which is then filled with oxygen at a pressure of 15 atmospheres. The bomb being immersed in water (1,000 grams) ignition is effected by an electric current, and the rise of the temperature of the water observed. When combustion is complete (as shown by the water attaining a steady temperature) the products of combustion are allowed to escape from the bomb through drying tubes filled with calcium-chloride, the bomb during this period being heated in an oil-bath to a temperature of 105° C. The difference of weight of the calcium-chloride tubes before and after the passage of the gases gives the weight of water for the required correction. A complete set of observations occupy about two hours.

The Paper describes in detail the construction of the bomb, and the method of using it.

A. S.

Compressibility of Gases. A. Leduc and P. Sacerdote.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxxv. 1897, p. 297.)

One of the Authors has already shown that if the compressibility of different gases at about atmospheric pressure is represented by

$$\frac{P_0 V_0}{PV} - 1 = A\,(P - P_0),$$

the product $A\,\pi$, of the coefficient A and the critical pressure of the gases, is an increasing function of their critical temperatures. The Authors have now determined the compressibilities with great accuracy, using a three-bulb tube, instead of a graduated tube as formerly. The apparatus was very carefully calibrated, an accuracy of $\frac{1}{100{,}000}$ being obtained. The temperature in the compressibility experiments was read to $\frac{1}{200}$° C. The experimental accuracy permitted the use of the parabolic formula

$$\frac{P_0 V_0}{PV} - 1 = a\,(P - P_0) + 2b\,(P - P_0)^2,$$

which gives, instead of the above A,

$$A' = a + 2b\,(\epsilon\,\pi - P_0)$$

at the pressure $\epsilon\,\pi$, that is, a certain fraction ϵ of the critical pressure. (ϵ was taken $= \frac{1}{76}$.) Points were plotted having for abscissas the critical temperatures and for ordinates the values of $A\,\pi$ (π being measured in atmospheres), and out of the eighteen gases tested fourteen fell on the same curve, three (CH_4, CH_3Cl, NH_3) being plainly above, and one (H_2S) plainly below the curve. As it did not seem possible to attribute the position of these four to experimental errors, the Authors think that the gases arrange themselves in three series. Considering the normal series, the curve is represented approximately by the equation

$$Z = m\,x^2 - n\,x^3 + p\,x^4,$$

in which

$$x = 175 + \theta,\ m = 135 \times 10^{-5},\ n = 338 \times 10^{-8},\ p = 145 \times 10^{-10}.$$

Assuming the critical temperatures in general to be exact, and also a certain number of the critical pressures (particularly CO_2, N_2O, CN), the above equation gives 67 atmospheres for the critical pressure of C_2H_2 instead of 68 (Dewar), and for HCl it gives 83 atmospheres instead of 86 (Dewar), or 96 (Vincent and Chappuis). The Authors intend redetermining this latter experimentally. Assuming the oxide of methyl to belong to the normal series, the Authors find for the critical pressure 57 atmospheres, and $A' = 271 \times 10^{-6}$. They are also determining the critical constants of phosphoretted hydrogen in order to further test the law.

J. B. H.

Solidification. A. HEYDWEILLER.

(Annalen der Physik und Chemie, vol. lxi., 1887, p. 527.)

The Author examined the densities of various organic bodies in the solid and liquid state. The following are the results for their respective melting-points, Δv denoting the maximum variation of density in passing from the liquid to the solid state, as measured with the mercury dilatometer :—

	Δv.
Benzol	0·1304
Phenol	0·0540
Menthol	0·0653
Thymol	0·0709
Stearic acid	0·1387 (min.)
Naphthalene	0·1454

The internal pressure must increase during solidification to a much greater extent than assumed by Van der Waals.

E. E. F.

Thermal and Electrical Conductivities of Carbon. L. CELLIER.

(Annalen der Physik und Chemie, vol. lxi., 1897, p. 511.)

In metals of approximately equal specific heats per unit volume the ratio between the electrical and thermal conductivities is the same for all. The Author ascertained whether the same relation held good for carbon. The specimens of carbon tested were graphite, arc-lamp carbon (Berlin), arc-lamp carbon (Paris) and gas-retort carbon, their respective densities being 1·698, 1·467, 1·567 and 1·627. The thermal conductivity was determined by placing a rod of the carbon, heated to a known temperature, upon a conducting basis kept at a constant temperature, and surrounding it with air at the same temperature. The flow of heat then obeys a simple differential equation, and the temperature of several points along the rod may be determined by thermo-couples. The constant temperature of the base and the air was maintained by a flow of tap-water. The thermo-couples employed were very fine iron and constantane wires soldered to a copper deposit on the carbon by means of tin. The following Table shows the results. T is the temperature, C_1 the specific heat per unit-volume, K_t the thermal, K_e the electrical conductivity.

—	T	C_1	K_t	K_e	$\frac{K_t}{K_e}$
	°				
Graphite	6·84	0·3055	0·701	$13{\cdot}049\times10^{-9}$	$53{\cdot}720\times10^{6}$
Retort-carbon	9·04	0·2782	0·400	$185{\cdot}360\times10^{-9}$	$2{\cdot}158\times10^{6}$
Arc-carbon, Paris	7·83	0·2667	0·494	$267{\cdot}880\times10^{-9}$	$1{\cdot}844\times10^{6}$
„ Berlin	9·04	0·2488	0·367	$146{\cdot}320\times10^{-9}$	$2{\cdot}509\times10^{6}$

For metals the ratio $\frac{K_t}{K_e}$ varies between $0{\cdot}07$ and $0{\cdot}12 \times 10^6$. The thermal conductivity of carbon is fifteen or twenty times greater than would follow from its resistivity if the metallic relation held good. Carbon, therefore, occupies an exceptional place.

E. E. F.

Tri-phase Currents. F. Vogel.

(L'Eclairage Electrique, vol. xii., 1897, p. 289.)

This is a somewhat lengthy mathematical Paper on the determination of the currents in a tri-phase system in terms of the resistances of the three conductors, their coefficients of self- and mutual-induction, and the impressed electromotive forces.

W. G. R.

Current Curves. H. Armagnat.

(L'Éclairage Électrique, vol. xii., 1897, p. 346.)

The Author divides his Paper into two parts, one dealing with methods of plotting current curves by the step-by-step process, and the other with types of apparatus designed to give the curve in a continuous manner. The first part describes the contact-makers of Joubert and Blondel, and shows diagrammatically the arrangements adopted in each case. The second part describes Blondel's oscillograph and Abraham's rheograph. The rheograph differs from the oscillograph in having a long natural periodic time, and consists of a movable coil, which carries the current under observation, placed in a strong magnetic field. The curve is traced on sensitized paper by a beam of light reflected from a mirror attached to the coil.

W. G. R.

Thermic Mercury Ampere-meter. Ch. Camichel.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxxv., 1897, p. 20.)

An apparatus is described for measuring amperes by passing the current through mercury which surrounds a thermometer.

A. D.

Standard Mercury Thermic Voltmeter. CH. CAMICHEL.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxxv., 1897, p. 90.)

An apparatus is described in which a thermometer column of mercury is put in circuit, in series with a suitable resistance, and the whole surrounded by ice. The expansion of the mercury by the heat produced measures the pressure with great delicacy. In another form the current is passed through a platinum wire, which heats a volume of air and causes it to expand. The heat developed under an alternating current may also be used as a ready means of comparing the hysteresis of different samples of iron.

A. D.

Electrolytic Resistance measured with Constant Current.

R. MALMSTRÖM.

(Zeitschrift für physicalische Chemie, vol. xxii., 1897, p. 331.)

The Author's conclusions are: Using platinized electrodes of about 11 square centimetres, area resistances of over 1,000 ohms can be measured without difficulty and accurately to some tenths per cent.; resistances of some hundreds of thousand ohms can be measured without platinized electrodes.

S. S.

Resistance of Solutions under Temperature and Pressure.

S. LUSSANA.

(Nuovo Cimento, 1897, pp. 357 and 441.)

In the Author's previous Paper[1] he gave a description of the methods of measurement. In the first part of this Paper details are given of the various observations made to determine the temperature coefficient and pressure coefficient for a number of salt solutions. The salts are the chlorides of Ba, Zn, K, NH_4, N_a and H. The temperature coefficients are calculated and used in the reduction of the pressure observations, which could not all be made at precisely

[1] Nuovo Cimento, 1895, p. 263.

the same temperatures. The following Table out of many illustrates the results:—

BARIUM CHLORIDE, 0·142002 GRAM PER LITRE.

Pressure in Atmospheres.	Temperature.	Resistance under Pressure.	Resistance at Atmospheric Pressure.	Diminution of Resistance.
	°			
150	8·48	3,763·9	3,895·2	131·3
300	8·74	3,648·1	3,860·8	212·7
450	8·88	3,568·3	3,847·2	278·9
600	8·44	3,547·4	3,898·4	351·0
750	8·65	3,477·1	3,872·0	394·9
880	9·35	3,367·3	3,785·2	417·9

Similar observations are given for the same solution at intervals up to 77°.

In the second part of the Paper the following conclusions are given: That the electrical resistance of solutions sufficiently dilute diminishes for an increase of pressure. That the diminution gets less as the temperature is raised, rapidly at first and afterwards more slowly. There seems to be a temperature of inversion at which the resistance does not vary with the pressure. That the diminution is not proportional to the pressure, but grows much less rapidly. The values of the coefficient of change of resistance, referred to the resistance under one atmosphere pressure, point to a pressure of inversion. That the variation of resistance with temperature increased with the increase of pressure for the more dilute solutions, whilst it diminishes for the more concentrated solutions. That an increase of pressure tends to augment the degree of ionisation and to diminish the frictional resistance for the ions.

S. S.

Magnetic Elements at Potsdam in 1896. M. ESCHENHAGEN.

(Annalen der Physik und Chemie, vol. lxi., 1897, p. 411.)

The mean values, as deduced from hourly observations during the year, were:—

——	Value for 1896.	Variation from 1895.
Declination	10° 14′·3 W.	−5′·6
Horizontal intensity	0·18747	+0·00027
Vertical intensity	0·43404	+0·00012
Dip	66° 38′·4	−1′·4
Total intensity	0·47279	+0·00021

The plans for the magnetic survey of Germany are being completed. Within the next five years some two hundred and fifty stations in northern and middle Germany will be dealt with, thirty or forty of which be old trigonometrical stations.

E. E. F.

Induction-Coil Winding. G. T. Hanchett.

(Electrical World, New York, 1897, p. 59.)

If the secondary of an induction-coil consists of two sections, each able, separately, to give a spark of, say, 1 inch, the coils when connected in series may generate sparks of from 2 to 5 inches; but in practice they often fall within the shorter limit. The Author concludes that, in the ordinary induction-coil, the various sections of the secondary are ineffectively placed with respect to the magnetic field of the iron core. He assumes that the rate of change of magnetic flux through a section of secondary windings near the ends of the core is different to the rate of change through a section of windings at the middle, and that consequently the maxima of induction are not coincident throughout the length of the coil. This difference of phase is supposed to account for the diminished length of spark. It is suggested that the cores should be lengthened with a view to equalising the flux through all sections.

R. A.

Heat of Hysteresis. F. A. Weihe.

(Annalen der Physik und Chemie, vol. lxi. 1897, p. 578.)

The determination of the heat of hysteresis is complicated by the presence of Foucault currents. To eliminate these, the Author exposed bundles of fine iron and steel wires to an alternating field from an 8-pole dynamo. The following Table shows the results of these and previous determinations:—

——	R.	Maximum Magnetization.	Frequency per Second.
	Per cent.		
Warburg	68	2,370	41 to 2
Tanakadate	80	1,370	28 to 400
Weihe, iron	80	260	55·8
„ steel	75	140	55·8

R is the ratio of the actual to the theoretical heat as deduced from the hysteresis loops. The actual heat was found by the ice-calorimeter.

E. E. F.

The Electric Arc. A. Blondel.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxxv., 1897, p. 164.)

On connecting an electric arc, by a rotating commutator, alternately (600 times per second) with a galvanometer and in the circuit of a constant current, and estimating the alleged counter electromotive force of the arc, it is found to stand in any case below 0·15 volt; whence the arc is equivalent to some kind of resistance.

A. D.

Electrolysis of Copper Sulphate. C. Ullmann.

(Zeitschrift für Elektrochemie, vol. iii., 1897, p. 516.)

The Author examines the condition under which black copper is separated by a large current at a copper kathode placed horizontally. With different current-densities the time from the making of the current until the separation of the black deposit and the formation of bubbles of gas is observed. He finds that for a given solution the product of the current strength and the square root of the time is approximately constant. When the strength of the solution is 0·25 gram equivalent of $CuSO_4, 5H_2O$ per litre the value of the constant is 4·6.

S. S.

Smokeless Powders for Blank and Sporting Ammunition. F. Hess and J. Frigall.

(Mittheilungen über Gegenstände des Artillerie- und Genie-Wesens, 1896, p. 441.)

The object of the experiments described in this Paper was to elaborate a smokeless powder which could be used in army manœuvres, and which could be produced at a lower price than the smokeless powder used for ball cartridges. Among the chief conditions which a powder of this kind should fulfil are the following:—The charge should, when ignited by means of the regulation cap, give approximately the same report as ball cartridge with as little smoke and flame as possible. No further tamping should be necessary than a plug or wad which would be disintegrated within twenty-five paces of the muzzle of the rifle. There should be neither chemical nor mechanical action upon the rifle, and the cartridge cases should be capable of repeated use. The gases given off during the combustion of the powder must not be injurious, and the powder itself must be stable.

The first experiments were made with nitro-glycerine, distri-

buted in a fine state of subdivision, upon various fibres and loose textile fabrics. In many cases the results of such cartridges were satisfactory; but it was found impossible to distribute the nitro-glycerine upon the fibre with sufficient regularity. Even mixtures of nitro-glycerine with cellulose were very irregular in their action; the addition of gelatinized nitro-cellulose produced no perceptible improvement. The further addition of charcoal proved advantageous, but the ignition was rather too slow. Powders containing various proportions of barium nitrate were then tried, and some gave excellent results. On the large scale, however, it was found that such powders gave too much flame especially when fired in volleys.

Powders containing nitro-glycerine as chief propulsive agent, having been found unsuitable experiments were made with nitro-cellulose. When the nitro-cellulose was gelatinized, and the gelatinizing agent subsequently removed by boiling in water, the powder obtained was liable to dust and, unless thoroughly purified, a considerable flame was projected from the muzzle of the rifle. Experiments are still in progress on a manufacturing scale with these nitro-cellulose powders. Full particulars of the various mixtures used for powders are given, and the Authors consider that some of them might be suitable for sporting purposes.

W. F. R.

INDEX

TO THE

MINUTES OF PROCEEDINGS,

1896-97.—Part IV.

N.B.—Titles in italics refer to Original Papers, and those selected for printing only are further distinguished by the suffix "(S.)," or "(St.)," the latter denoting Students' Papers. Abstracted Papers are not so indicated. The titles of the Conference Notes included in the present volume are distinguished by the suffix "(C.)."

422 a

LONDON:
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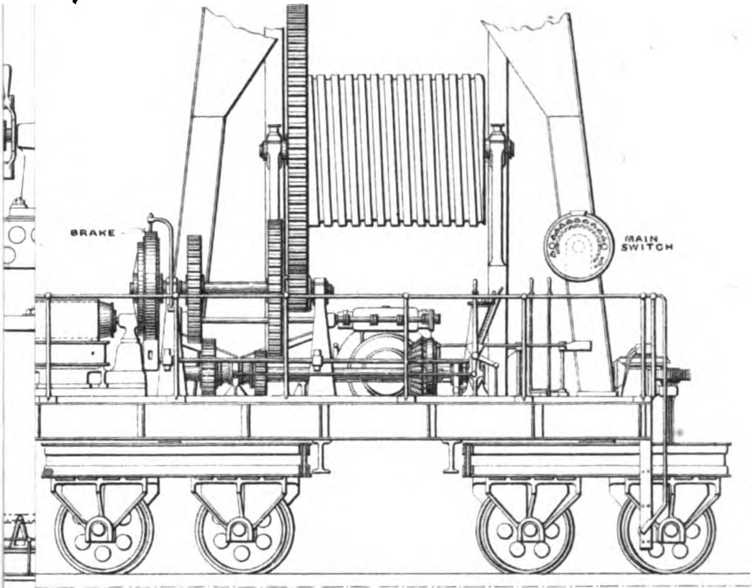
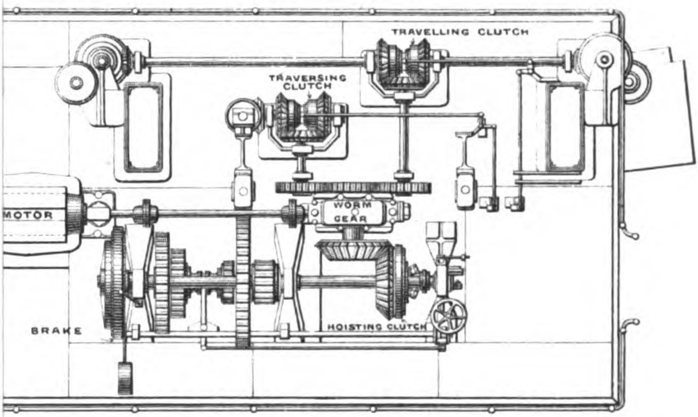
Figs: 6.



SIDE ELEVATION

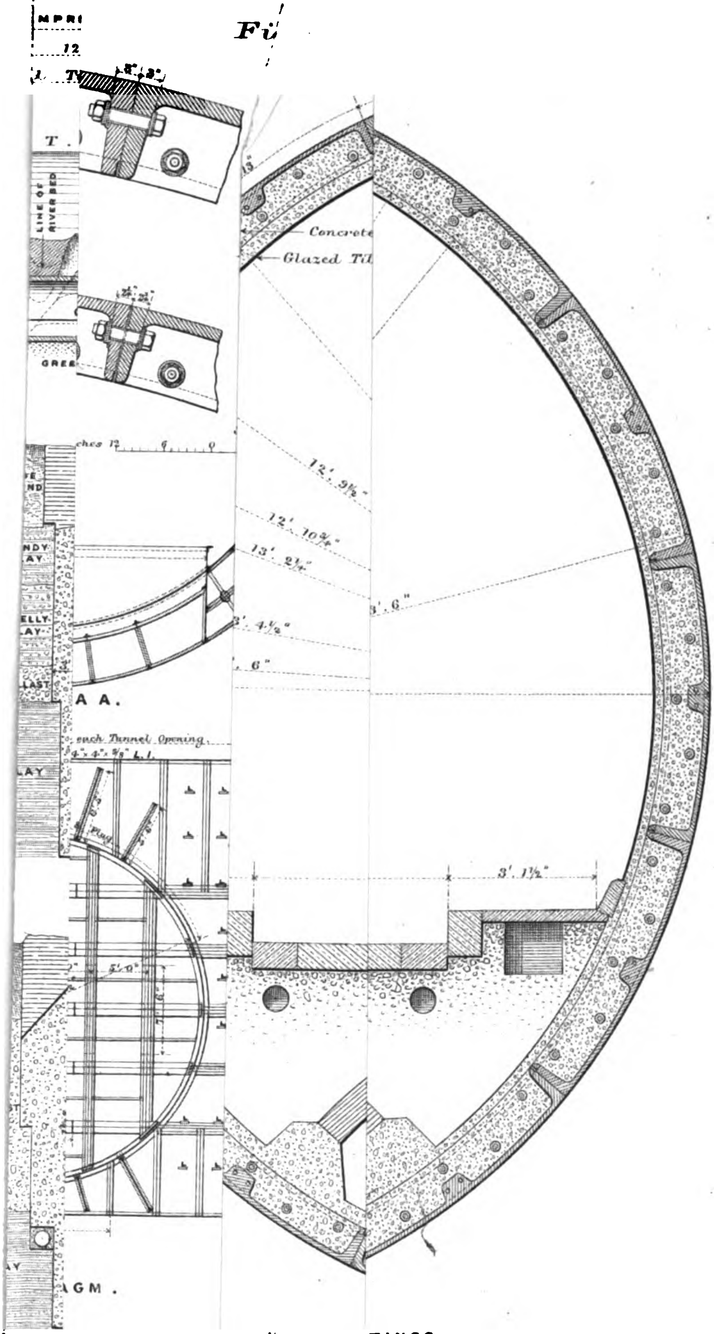


PLAN
ARRANGEMENT OF GEARING

THOS KELL & SON LITH 40 KING ST COVENT GARDEN.

FALL TUN

PLATE 2.



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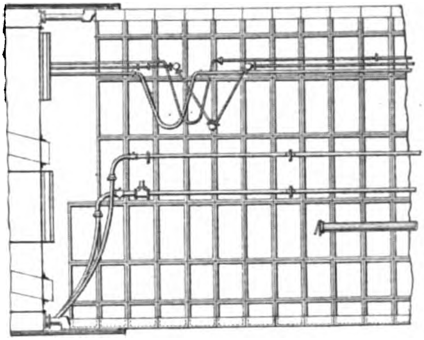
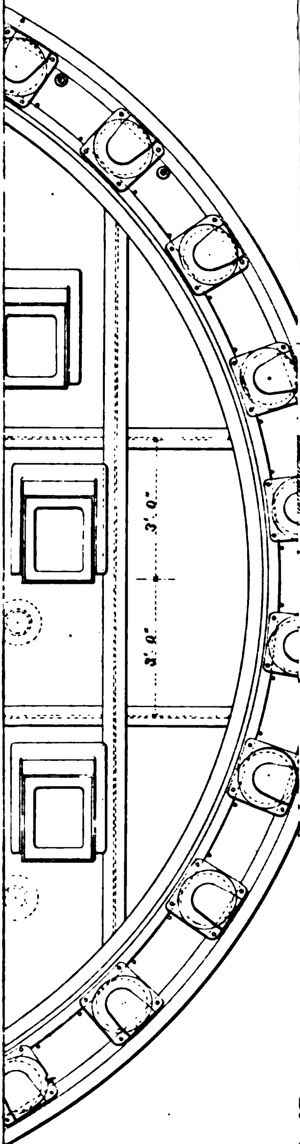
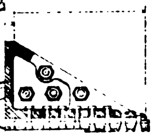
Kell & Son, Lith. 40 King St Covent Garden.

PLATE 3.



LONGITUDINAL SECTION RIGHT-HAND SIDE.





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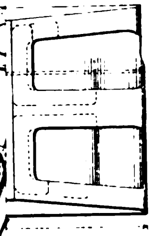

EEL SEGMENT.

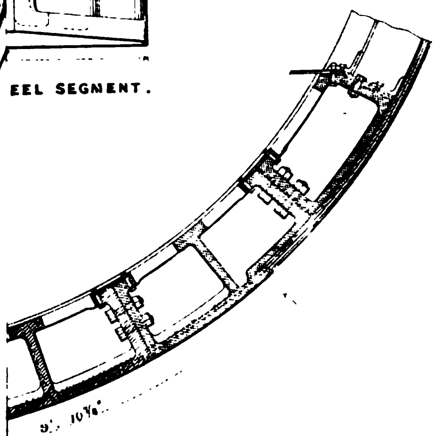

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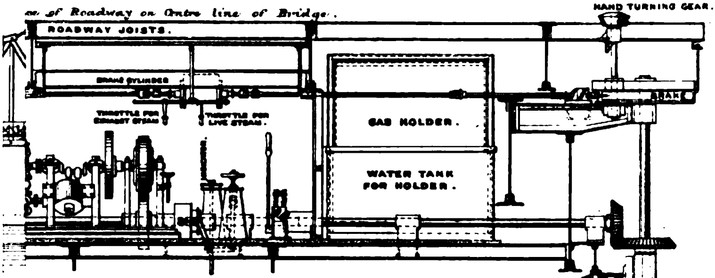
Fig: 11.



...GITUDINAL SECTION OF ENGINE ROOM.

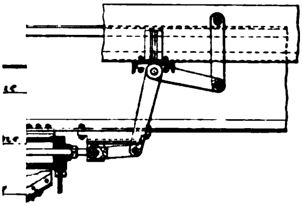
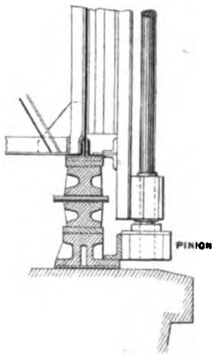
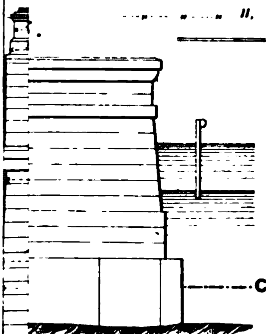


Fig: 12.



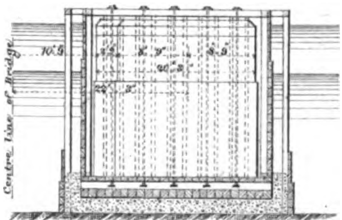
SCALES.

Scale for Figs. 2.	1 Inch	=	64 Feet
„ „ 3.6	1 Inch	=	24 Feet
„ „ 10 & 12	1 Inch	=	2 Feet
„ „ 11.	1 Inch	=	8 Feet

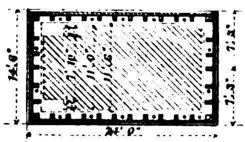


...ALF ELEVATION OF PIER II.

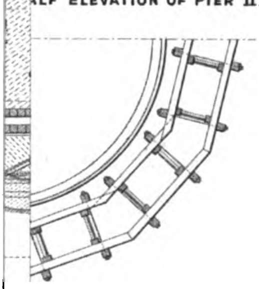
Figs. 6.



LONGITUDINAL SECTION THROUGH OPEN CAISSON.



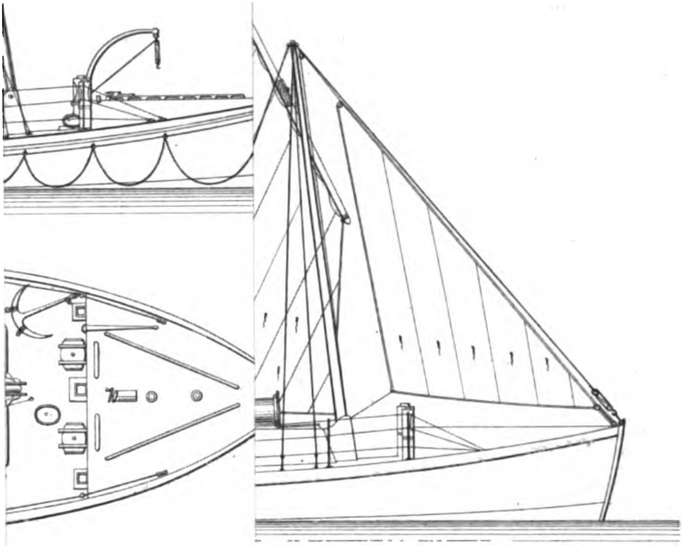
HORIZ^L SECTION THRO' OPEN CAISSON.
FOUNDATION OF PIER No. III.

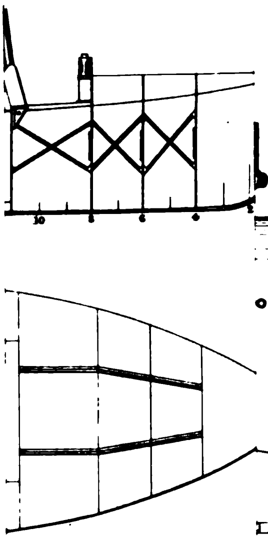


...UARTER TOP VIEW.

...II.

THOS KELL & SON, LITH. 40 KING ST COVENT GARDEN.





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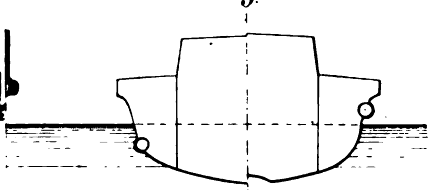
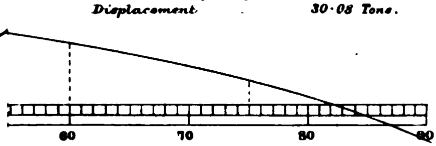


OM. SECT AT FRAME 22. SHOWING "AHEAD" OUTLET. SECT AT FRAME 16. SHOWING "ASTERN" OUTLET.

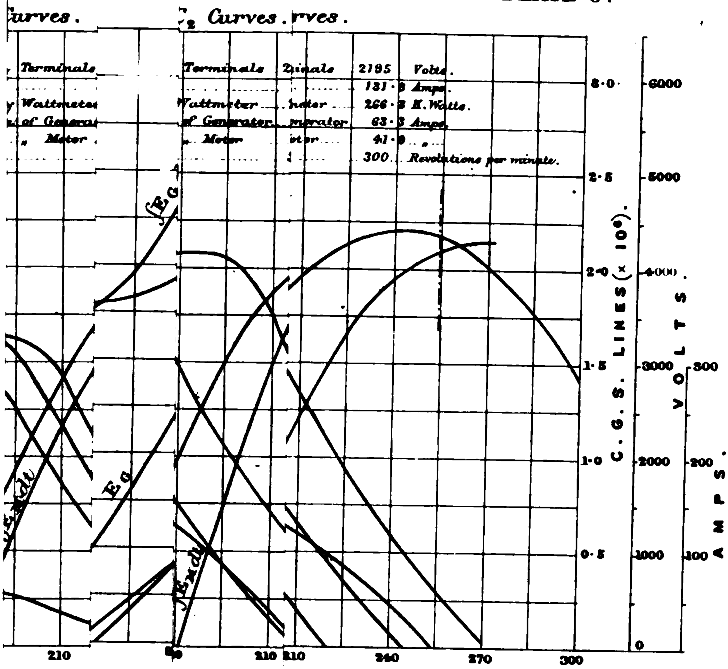
Maximum Righting Arm = 13°
Displacement 30·08 Tons.



VE.

THOS KELL & SON LITH. LONDON.

TIN


Curves.
Curves. rves.
Terminals
Wattmeter
of Generator
Motor
2195 Volts.
131·3 Amps.
266·3 K. Watts.
63·3 Amps.
41·9 "
300 Revolutions per minute.
∫EG
EG
∫Exdt
C. G. S. LINES (× 10⁶).
VOLTS
AMPS.
8·0
2·5
2·0
1·5
1·0
0·5
6000
5000
4000
3000
2000
1000
0
300
200
100
210
240
270
300

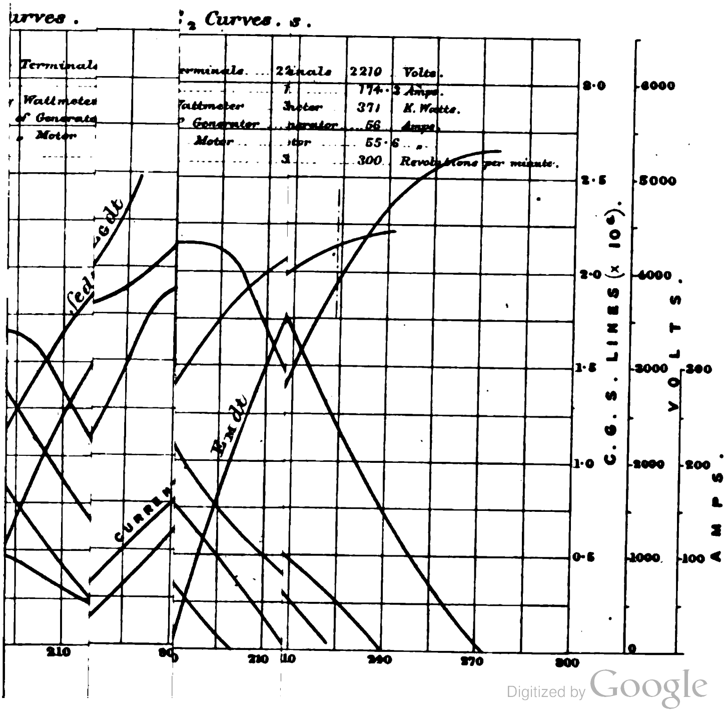
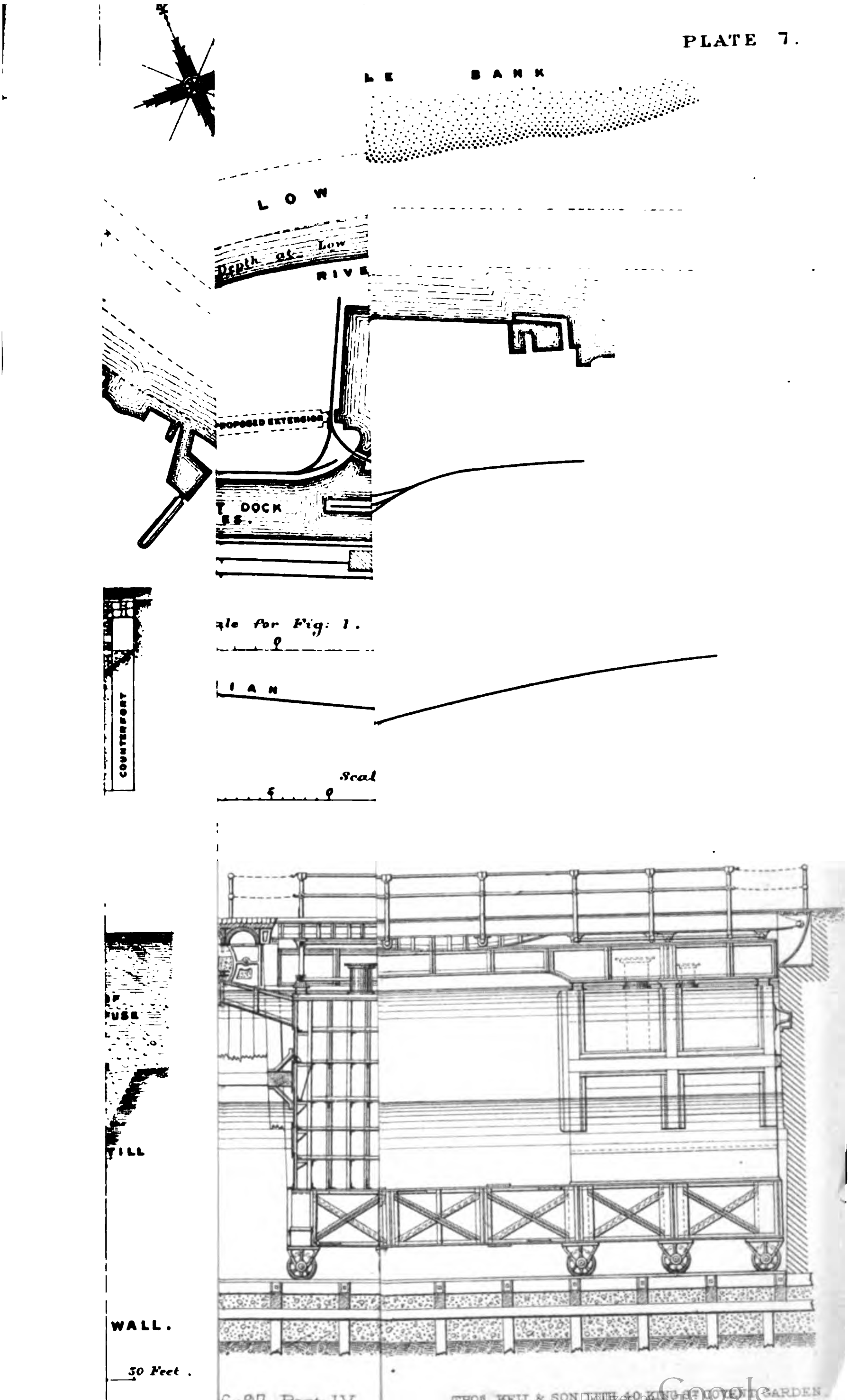

Curves.
Curves. s.
Terminals
Wattmeter
of Generator
Motor
2210 Volts.
174·3 Amps.
371 K. Watts.
56 Amps.
55·6 "
300 Revolutions per minute.
∫Edt
CURRENT
Exdt
C. G. S. LINES (× 10⁶).
VOLTS
AMPS.
8·0
2·5
2·0
1·5
1·0
0·5
6000
5000
4000
3000
2000
1000
0
300
200
100
210
240
270
300

PLATE 7.



THOS KELL & SON LITH 40 KING ST COVENT GARDEN